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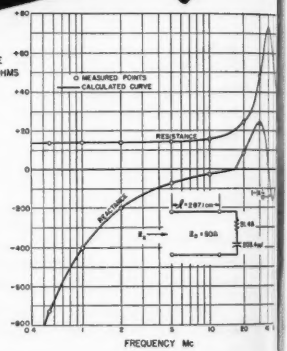

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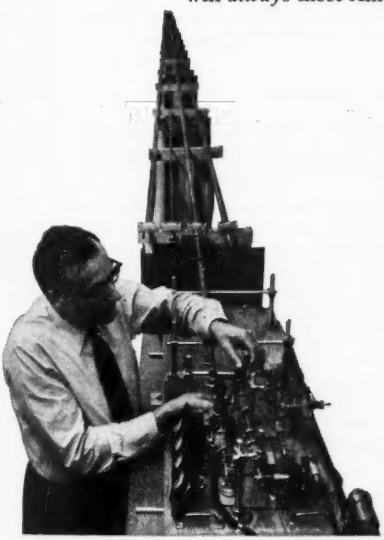

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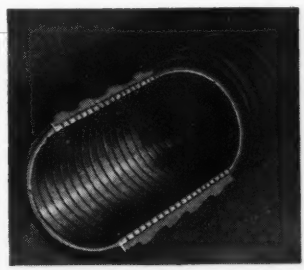

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The Humanistic-Social Studies in the Engineering Curricula*

By DR. EDWIN S. BURDELL

President of The Cooper Union

To this title, "The Humanistic-Social Studies in the Engineering Curricula," might well be added the prefix, "the problems of establishing and maintaining," for after all the definition and values of the humanistic-social stem have been stated elsewhere by many leaders in engineering education. I shall undertake to discuss this subject from four points of view: integration versus articulation, problems peculiar to the independent engineering college and to the university engineering college, how to find the time for inclusion of the humanities in a professional curriculum, and, finally, tailor-made versus ready-made humanistic-social programs.

Generally speaking, there are two ways by which the humanistic-social studies can be related to scientific-technological studies. One way provides an articulated relationship; the other, an integrated relationship. An example of the method of articulation is a plan whereby, following the pattern of preparation for medicine and law, a one- or two-year liberal arts program can be required as a prerequisite for professional education. The arguments in favor of this arrangement, so I have heard, are that the young college student can catch more culture by being completely immersed in it, that the sequences of liberal arts and professional training are more meaningful because each is concentrated in a smaller time-capsule. I disagree with this theory because, in the first place, it places a road block of subject matter between the eager high school student and his chief interest, science and its applications, causing him perhaps a life-long emotional distaste for having anything more to do with the humanities. Furthermore, it gives him the notion that, having "passed off" those requirements, he can forget the field and devote himself exclusively to technical specialization. I doubt that there will be much carry-over to the young engineer's professional beginnings from this too early and too concentrated humanistic exposure. In fact, I am inclined to refer to articulation somewhat unkindly as a preheat treatment, which casehardens the embryo engineer against the very interests, attitudes, and philosophies that the liberal studies aim to awaken and stimulate.

Another approach to articulation is by an arrangement whereby the junior year liberal arts student transfers to an independent engineering college for his fourth and fifth years. He usually receives a bachelor of arts degree and his engineering degree at the same time. This is a plausible way of having your cake and eating it too—if it works! But it robs the liberal arts student of his senior year, the final crowning year of his undergraduate experience. It denies him the satisfactions of completion of his curricular and extracurricular program, and cuts off abruptly the associations built up on the campus, which in a small liberal arts college are usually very warm and intimate. It pitchforks him on to another campus where he is a stranger and where in two

* Presented at the semi-annual meeting of the Mid-Atlantic Section, ASEE, Polytechnic Institute of Brooklyn, Dec. 4, 1954.

years he can scarcely hope to make a place for himself in the undergraduate scheme of things. This arrangement exists between many liberal arts colleges and some of the leading engineering schools. It bears watching and for a certain type of student to whom undergraduate life is relatively meaningless, of course, the loss of the values that I have just mentioned is no real loss at all.

Now, turning to integration, I would like to point out that this method of introducing the humanistic-social studies offers continuity and flexibility. By this method a four-year vertical sequence of one three-hour-a-week course each semester can amount almost to the equivalent of one full year of liberal studies in the engineering school. Pedagogically, an uninterrupted contact with the liberal studies during the pursuit of a science and engineering course does much to exemplify the wholeness of knowledge and should go far to dispel the false notion of a dichotomy between general and technical education. This arrangement also facilitates a correlation among the forces at work in society at a given time; for example, between the intellectual ferment and the social upheavals of the eighteenth century. It can provide understanding of the impact of the prevailing mores on the inquiring mind throughout the history of western civilization. Teachers of the physical sciences and social science teachers can join forces in bringing to life the relationship between science and society so that the student will be in a position to develop his own personal philosophy of life along with a real understanding of the goals and responsibilities of his chosen profession.

Such integration provides for building one course upon its predecessor, offering more difficult and profound subject matter in the upper years, thus avoiding superficiality and lack of depth. It may, under a scheme that we prefer at The Cooper Union, provide for matching the highly particularized professional engineering studies in the senior year with generalized philosophical concepts, while, in the early years, the basic generalizations of physics, chemistry, and mathematics are matched by particularized disciplines of English composition, speech, and so on. Finally, it provides to humanities teachers the opportunity to obtain the satisfaction of offering more advanced material at higher standards than would be possible if they had to confine their efforts and interests to the immature first- and second-year students.

Two Frames of Reference

My second point for discussion is the problem of teaching the humanistic-social studies within the two frames of reference —the independent engineering school and the university engineering school. The great advantage in the independent engineering school is that the humanistic-social faculty members are an integral part of the science and engineering faculty. They share the common objectives of engineering education with their colleagues. Subject matter fields are apt to have fewer rivalries if all of the humanistic-social studies are taught by men in a single humanities department. Communication among the science, engineering, and humanities teachers is apt to be good and the humanities teachers themselves are apt to be more enthusiastic about their jobs because they have an undivided loyalty to a common objective.

Now, of course, there are disadvantages. The smaller independent engineering colleges may not be able to afford the diversity of teachers desirable for a broad offering of subject matter. Hiring of part-time teachers defeats the unity that I mentioned above. Then there is a tendency to dispense with the "frills" and set up courses with such misleading titles as "Engineering English," "Engineering Economics," and so on. From the standpoint of the ambitious specialist in the humanities and social sciences, there appears to be little or no opportunity for research and graduate teaching and the

job looks like a dead end with little or no job satisfaction or professional prestige.

The advantages to the humanistic-social stem in the university engineering college lie in the wealth of talent that the university offers. These cultural resources could be of tremendous value in enriching a sequence in the liberal arts and social sciences. However, the danger of not making the most of these riches is exceeded only by the difficulty of achieving a satisfactory allocation of teachers and classes. For instance, liberal arts teachers assigned to teach engineering students are likely to be young graduate students primarily interested in pursuing advanced work in their own fields of specialization. They are not apt to be invited to participate in curricular planning; hence, they cannot share the enthusiasm or appreciate the objectives of engineering education. The dean of engineering with the best of intentions may allot, if his faculty permits, a certain number of credits in the humanistic-social stem in the hope that the engineering students, innocent of intellectual dietetics, will choose with discrimination from an educational smorgasbord. Of course, there are exceptions; and one of the best situations I know of was that which existed at The Ohio State University while Miss Sada Harbarger, of the English Department of the Arts College, was teaching English and literature to the engineering students. Miss Harbarger, on her own initiative, did undertake to find out what the engineering faculty wanted to accomplish and went ahead and constructed and taught the courses.

When engineering students do not have their own sections in the humanistic-social studies and are compelled to take those studies with liberal arts students, they find two significant difficulties. First of all, the liberal arts students presumably are going on for advanced work; hence neither the instructor nor the members of the class finds any common interest with the engineering student who is limited to one or two courses in any humanistic subject matter field. Secondly, elementary teaching in the liberal arts college of a large university is apt to be in large lecture and quiz sections affording little opportunity for discussion and individual attention, whereas the engineering student is accustomed to small classes and close association with his science and engineering teachers.

My third topic is how to find the time. It has been recommended that the humanistic-social stem should include history, economics, and government, wherein knowledge is essential to competence as a citizen, and literature, philosophy, psychology, and fine arts, to broaden the engineer's intellectual outlook. This is a large order and we all know the curricular jug is full. Hence, my advice is to do a more efficient job of teaching of the scientific-technological studies, minimize the descriptive material and the repetitive drill, and encourage solving a few problems on the basis of science principles rather than emphasizing a large number of problems. Perhaps an honest re-appraisal of the scientific-technological curricula would lead to fewer courses in all and also fewer courses given simultaneously. Engineering faculties will have to get accustomed to postponing more and more technology to the graduate years. Indeed they might well reduce specialization in the undergraduate program by experimenting with a single engineering curriculum leading to a bachelor of science in engineering. The American Society for Engineering Education and the Engineers' Council for Professional Development have suggested in the last six months that more thought be taken of ways to simplify and intensify engineering education.

Fundamental Re-grouping

In my opinion, the answer does not lie in the five-year undergraduate program. The evidence is not convincing that under this lengthened plan the pace is slower or the amount of humanistic-social subject

matter is greater. Not lengthening but shortening is what I would propose for professional education, and that by a fundamental re-grouping of our American educational system.

Specifically, I propose that grades 7, 8, 9, and 10 be combined into what, for want of a better title, I would call a Middle School. Grades 11 and 12 would be brought up to the European standard of the lycée or gymnasium—terminal for most students, but preparatory for those others who have demonstrated their intellectual capacity for university and professional training. It is hard-headed realism, not intellectual snobbery, to say that our American educational system cannot afford the extravagance of offering higher education to a vast number of unqualified youth. On the other hand, our dynamic society requires urgently that those intellectually qualified but economically handicapped be given the opportunity to train for professions. I have said elsewhere that there is no place in higher education for the mediocre student. Annual tuition in the private college costs up to nine hundred or a thousand dollars and campus living up to another eleven or twelve hundred dollars. Yet this huge expense represents only a part of the total cost of education that must be made up out of endowment income or alumni giving. In this situation, the American parent and the American educator have to come down to earth and provide for those students most able to benefit by the intellectual training. When the increase of college-age population hits the colleges with its full impact, they will be forced to decide between selecting qualified students or expanding to accommodate without discrimination all those who apply.

On another level of education the subprofessional technical institutes must be greatly expanded in number to prepare men and women for the supervisory functions—ever more demanding in an era of automation. Adult education, both avocational and vocational, will be needed as leisure time increases and as jobs change with a rapidly changing technology. For those who cannot afford post-high school education away from home and who are not destined for professional or sub-professional careers, the junior college will fill a great need. Unfortunately, the connotation of "junior" is belittling and should be modified. If some form of universal military training is superimposed on our present system of education, the need will become all the more acute for compressing and shortening the period of preparation for professional practice.

Whether or not my proposals for overall educational reorganization are accepted, whether professional education comes earlier or later in the student's life, whether it is more or less selective, we all, I think, are agreed on the importance of a program of humanistic-social studies in engineering education. But what program? Shall it be tailor-made or ready-made? In the effort to live up to and implement the recommendations of the famous 1940 and 1944 reports of the Society for the Promotion of Engineering Education, some deans of engineering were inclined to apply a formula instead of deriving enriched curricula out of the resources of their own institutions. No educational program can be thus produced ready-made with mechanical uniformity. Teachers, library, budget, and the relations of the engineering school to the university all are factors that need to be taken into consideration in setting up each individual sequence of humanistic-social studies. The 1944 "Report of the Committee on Engineering Education After the War" recommended an allotment of time equivalent to one three-hour course extending throughout the curriculum, and on the average somewhat more. But caution should be exercised to limit subjects to those that can be staffed adequately and taught enthusiastically. A few well-taught subjects are much to be preferred to a smattering of poorly taught courses.

The Committee referred to above said under the topic of "Program and Method of Instruction": "While the selection of subject matter suitable to the achievement of the aims of humanistic-social studies is important, we believe that this will present less difficulty than will devising appropriate methods of instruction. . . .

"The knowledge of miscellaneous details of the subject matter selected is less important for engineering students than is the acquirement of the ability to understand, to analyze, and to express the essentials of an economic, social, or humanistic situation or problem, and to appreciate the implications and relationships of such problems to the life and work of an engineer.

"Formal expository methods are often used in these fields. We believe they are less effective in accomplishing the results advocated than a method which places responsibility on the student himself. Such a method should require him to read, to question, to seek evidence, to weigh, to judge, to accept, and to express the results of his efforts in written or oral form both in school and in life situations."

And now I would like to comment briefly on a few topics related to the four I have discussed. The impact of advanced Reserved Officers Training Corps is definitely hampering to the upperclass student who has devoted all his twelve elective credits to military subjects to the exclusion of humanistic-social electives and even some science electives. The dean of an engineering college in a university can do little about this detrimental substitution because policy is determined at a higher level, but I understand that in some independent engineering colleges advanced R.O.T.C. is regarded as a paid extracurricular activity for which no academic credit is given.

Another way in which engineering colleges might cope with the shortage of time available for humanistic-social studies is to make more of the learning possibilities inherent in well-administered student activities, such as publications, debating, dramatics, student government, and so on. There is no reason why these extracurricular activities should not enjoy status and prestige equal to those of the student branch chapters of the various engineering societies. Again referring to the Committee on Engineering Education, its report recommended, under "Methods of Organization": "Encourage engineering students to participate in expressional activities (music, dramatics, public speaking, painting, etc.); and in student organizations concerned with public and social problems; provide organized opportunities for attending the theatre, concerts, art exhibits, etc., and assign themes and reviews based on these events."

Conclusion

Finally, let me conclude with the observation that too few of our students ask the meaning of what they are doing, or speculate about the significance of their vocations in the total framework of human life. Until too late, they fail to see that the difference between vocational training and professional education lies not so much in the subject matter studied but rather in the spirit in which it is approached—the breadth of view, the kinds of questions raised, and the value judgments taken. The humanistic-social stem will never succeed in reaching its objectives of providing the student with the basis of a sound personal philosophy unless the student is convinced that the pursuit of such studies is valuable and significant. Motivation for such studies can be found by the student in the enthusiasm of the instructor of mathematics perhaps even more than in the exhortation of the English teacher. The faculty, all of its members, must share a deep enthusiasm for a deep and broad approach.

It is well to consider as we have here the problems of humanistic-social studies in the undergraduate engineering curricula. But we must not lose sight of their

ultimate goal, the training of future leaders, not only conscious of three thousand years of cultural heritage, but also alive to their responsibilities to American society in the second half of the twentieth century. In dedicating ourselves to turning out specialists in science and technology, let us not forget that the last word in policy decisions will be made by the generalist, one whose education and experience in law, engineering, or business have taught him to equate legal, physical, economic, and human values. Aren't we aiming to equip most of our graduates ultimately to be able to serve among those generalists?

College Notes

The **Duke University** College of Engineering has established a new program to combine liberal arts and engineering studies. Duke will cooperate with selected liberal arts colleges throughout the United States in the "three-two program," which will get underway this Fall. The program will be operated along with the University's regular four-year engineering curriculum. Only a limited number of outstanding students will be admitted.

Each participant will attend a liberal arts college for three years and then the College of Engineering for two years. After a total of five years, the liberal arts college will award a Bachelor of Arts or Bachelor of Science degree, and Duke will award a Bachelor of Science degree in engineering.

The **Illinois Institute of Technology** Alumni Association presented a distinguished service award to Arthur B. Bronwell, president of Worcester Polytechnic Institute and former ASEE Secretary on May 6.

Plans for two Special Summer Programs on "Strain Gage Techniques" to be given at the **Massachusetts Institute of Technology** during the 1955 Summer Session, have been announced. "Fundamentals of Strain Gage Techniques" will be given from July 25 through July 29, and "Applications of Strain Gage Techniques" from August 1 through August 5. Full details and application blanks may be obtained from the Summer Session Office, Room 7–103, Massachusetts Institute of Technology, Cambridge 39, Massachusetts.

The Glenn L. Martin Institute of the **University of Maryland** was dedicated recently. Erected at a cost of $8.5 million, the institute is made up of eight buildings which house the entire College of Engineering and many of the academic and research departments of the College of Arts and Sciences.

The Complimentary Role of Physics and Mechanics in Engineering Education

By GLENN MURPHY

Conference Secretary, Professor and Head of Aeronautical Engineering, Iowa State College

Among the many ideas being explored in the continual attempt to improve engineering education is that of eliminating unnecessary duplication of effort in allied departments. At the outset, it is evident that some duplication of subject matter, particularly as it relates to principles, is essential. However, undue duplication robs the student of the opportunity to receive instruction in additional areas which may be vital to his continued growth and development throughout his professional career.

One possible area of duplication is that of mechanics as it is usually taught in the department of physics and later in one or more departments in engineering. To explore the teaching of mechanics, the National Science Foundation sponsored a conference of about twenty of the leading educators in the field. The conference was organized by the Physics Division and the Mechanics Division of the American Society for Engineering Education under the guidance of Prof. F. L. Singer of the Engineering Mechanics Department of New York University, who is also current chairman of the Mechanics Division of ASEE. The conference was held at the Gould House of N. Y. U., 23–26 January 1955.

In evaluating the instruction in mechanics as it has been and is given by physics departments, the group found that in the majority of schools the courses in physics are considered prerequisite to engineering mechanics. As a result the student is exposed to a barrage of ideas, concepts, principles, formulas and solutions to problems at a rate well above that at which he can be expected to absorb them simply because so much material must be covered in so little time. The students quickly learn that grades are assigned on the basis of problems solved in examinations and problems are solved by formulas. Consequently, they place the emphasis on formulas and seldom attain the depth of understanding of principles that is desirable and increasingly essential. This is particularly true when the instruction is in the hands of graduate assistants.

As the conference progressed it became clear that the function of the first course in physics in an engineering curriculum should not be that of serving as a prerequisite to mechanics and other engineering courses. Instead, the course should be directed toward giving the student an understanding of the concepts and principles that are basic in our physical world. Applications of the principles in the physics department should not be directed toward the solution of those engineering problems that must be considered later in detail in engineering mechanics. Rather, the applications should be directed in such a way that the student will develop confidence in his reasoning ability, and his ability to arrive at correct conclusions when working with phenomena the details of which are not directly apparent.

In the physics course the emphasis should be on synthesis, or the building up of an understanding of laws and principles governing physical phenomena. On the other hand, the primary objective of the courses in mechanics in engineering

is that of predicting the behavior of real engineering systems. Consequently, the emphasis in engineering mechanics will necessarily be on analysis and problem solving rather than synthesis and principle development.

With these objectives the initial course in physics for engineers will not be subordinated to engineering mechanics in functioning as a prerequisite. The training in mechanics in physics departments and in engineering was visualized by the members of the conference as proceeding most advantageously in parallel, rather than in sequence, with numerous cross ties to lend mutual support, strengthening and balance. In this way the first course in physics may be better designed to serve as a base for later courses in atomic physics or nuclear physics for which increasing demand is expected to develop. With the broader scope of engineering physics as visualized by the conference, it is clearly evident that the instruction in the first course in physics for engineers must be in the hands of the most capable teachers who will give it sympathetic and dynamic treatment, and that it not be relegated as a chore for graduate assistants.

In considering solid state physics as a part of the physics program, it was brought out that the engineers are interested in a course at the junior or senior level that will give the students some insight of the behavior of materials so that the development of courses in engineering materials can proceed along other than strictly empirical lines. It was conceded that classical solid state physics is at the graduate level for physics majors.

Instruction in mathematics as it related to the problem was considered and led to the conclusion that the student should be introduced to the concepts and a working knowledge of calculus as early as practicable in his college curriculum. It is equally important that the mathematics then be used in the engineering courses.

The discussions culminated in the following statement which was adopted unanimously by the members of the conference.

"The conference found, after a careful analysis of the statements of the objectives of undergraduate instruction in both physics and engineering, that the objectives are not competitive in scope but actually complementary when the courses are properly planned and taught. It cannot be over-emphasized that the instruction by physicists will provide the engineering student with an understanding of physical phenomena basic to much of his later studies. On the other hand, the objective of instruction in mechanics by engineers is to achieve professional competence in the practical solution of problems encountered in engineering.

"We conclude, therefore, that there is an essential difference in the approaches to mechanics by the physicist and the engineer. There is a place and, indeed, a need for both of these approaches to the teaching of mechanics. The different objectives should continually be recognized and used as guides in planning courses.

Objectives of Physics Instruction in Mechanics

"The primary objective of physics instruction in an engineering or scientific curriculum is to provide the student with an understanding of the physical principles that describe nature, of how these principles have evolved, and of their scope and limitations. Such an undertaking must begin with the study of Newtonian mechanics. Great emphasis should be placed on the conservation principles. The generalization of these principles along with associated concepts has formed the basis for modern physics, including such special branches as atomic and nuclear physics and the physics of the solid state. With this approach, it is neither practical nor desirable in the physics course to devote attention to the development of facility in detailed application of physical laws to practical problems encountered in engineering practice. Stimulating problems should be

selected with a view to illustrating physical principles, and it is essential that they be accompanied by a challenging laboratory experience. These courses, approached in this manner, should provide an adequate base for the student's continued scientific growth.

"In order that the study of Newtonian mechanics be effective in setting the stage for a proper understanding of the concepts and methods of modern physics, it must be recognized that a significant difference exists between the older physics and most of modern physics. In modern physics a large amount of theory is often interposed between observations and the conclusions based on them. Nevertheless, the pedagogical approach in which macroscopic observations are used directly as a guide in building theory must first be employed, as it can in mechanics; the student must later be led to the present day methods of inferring conclusions regarding phenomena not directly observable. These methods are in fact used in kinetic theory, optics, and electricity, as well as in many topics of modern physics.

"To achieve this goal, the role of conservation laws in mechanics and electricity can hardly be over-emphasized. The study of mechanics should also include the dynamics of systems of particles, wave propagation, standing wave systems, etc. Valuable for later work in modern physics will be the study of resonant systems, such as the mechanical harmonic oscillator, accompanied by demonstrations or discussions of similar resonant systems in electricity, nuclear-magnetic resonance, and examples from acoustics and optics. It is in this spirit that instruction in mechanics makes a significant contribution toward the understanding of phenomena in atomic, nuclear and solid state physics.

Objectives of Instruction in Mechanics by the Engineer

"The prime objective of instruction in engineering mechanics is to provide the student with a useful understanding of the methods and principles needed to design and predict the performance of real engineering systems and structures. The preparation of engineers for creative design should be kept always in mind. Creative design requires as much ingenuity, imagination, and resourcefulness in the application of physical laws and principles and in making them useful to man as is required in the original formulation of them.

"In order to solve real problems of the great variety and number that are presented to the engineer, it is necessary that he become proficient in a systematic method of problem solution. Consequently, instruction in methodology is an essential part of engineering mechanics. Instruction must include ample emphasis on the following operations which are basic to engineering analysis.

"The student must learn to identify the essential elements and characteristics of each specific engineering problem. Is it, for example, one involving statics or dynamics, rigid or deformable bodies, a conservative, or a dissipative system? He must be able to select relevant information and data and recognize those which are not pertinent. In doing this an ideal model must be created and the problem made amenable to solution. The results based on the idealized model must next be interpreted in the light of the original real situation. The engineer must form a judgment of the extent to which he can rely on the results obtained on the ideal model, and finally he must be able to communicate this to others in suitable and usable form.

"The engineer must devote major emphasis to the formulation and evaluation of his problem quite apart from the necessary analysis. Instruction given the engineering student should reflect this fact.

"It is in this spirit that the instruction in engineering mechanics assumes a significant role as a springboard to a truly professional attitude and approach to all engineering situations.

Objectives of Instruction in Solid State Physics

"Before considering the place, if any, of solid state and nuclear physics in engineering curricula, it is desirable to consider the activities of physicists in these respective fields. In nuclear physics, the physicist is concerned with the quantitative behavior and structure of nuclei, the nature of forces involved between nuclear particles, and the interaction between nuclei and radiation. In solid state physics the physicist in seeking to develop an understanding of the properties of solids on the basis of their atomic constitution.

"To take part in the current activities in either of these fields requires a background and a working knowledge of quantum mechanics as well as of the general principles and conservation laws of classical mechanics and electrodynamics. Such knowledge can be obtained only through several years of study, generally including graduate work. This conference is convinced that there is no shortcut by which this knowledge can be given to undergraduate engineering students by means of a one or two-semester course in modern physics.

"On the other hand, an introductory course of one or two semesters' duration covering some of the topics mentioned above could be given following the general physics course. Such a course should broaden the training of the undergraduate engineer.

"It is the conviction of this conference that the time should not be taken from that now devoted to an understanding of the fundamental principles of mechanics, which should be required of all engineers. Instead, the conference recommends that the basic physics course be strengthened by greater emphasis on fundamental classical principles and conservation laws, and by an introduction to wave and quantum concepts. Inclusion of these topics is an essential introduction to the later study of solid state or nuclear physics. It is also recommended that as far as possible, such particles as electrons, protons and neutrons be used in the elementary physics course to illustrate general dynamical principles. In the case of existing two-year physics courses, it is the belief of the conference that some concepts of modern physics can be introduced without requiring additional time. In the use of one-year physics courses, an extension of time of at least a semester is recommended.

Mathematics Instruction as Related to Mechanics

"It is urged that the concepts of calculus be introduced in engineering curricula as soon as possible, preferably in the freshman year, and used in physics and engineering as soon as feasible.

Conclusion

"In comparing the different objectives and points of view of instruction in mechanics by physicists and engineers, it should be emphasized that the physicist uses problems and examples from experimental physics essentially for the purpose of developing by the inductive method those concepts and principles which it is his objective to have the student understand. The engineer, on the other hand, uses certain concepts and principles for the purpose of achieving the solution of practical engineering problems. This distinction should determine in a major way the essentially different character of illustrative material used in each area.

"If instruction in physics and engineering mechanics follows the objectives outlined, it appears that, although some duplication of content is inevitable and even desirable, the real duplication in terms of influence on the engineering student will be negligible. On the other hand, if instruction in physics follows in any major way the direction of application to engineering situations, or if instruction in engineering mechanics fails to emphasize the professional engineering approach, then this duplication will result in a serious waste of time.

"Consequently, it is evident that the preservation of the two different but mutually supporting points of view of the physicist and the engineer is a necessary condition for maintaining the progressive program of engineering education, which in these critical days is of vital interest to the entire nation.

"Finally, the conference recognizes that progress occurs through continuing experimentation, and therefore recommends that such an attitude be encouraged in the teaching and the curricular arrangements of physics and engineering mechanics."

Throughout the conference there was the recurrent theme that the improvement of engineering education, which is of vital concern to all, can be achieved through the enthusiastic participation of individual staff members in coordinated local programs of evaluation and improvement of teaching of engineers. While a conference of the type held at the Gould House can indicate general patterns of improvement, the details which constitute the real benefits must be worked out at each school in harmony with the particular local situation. It is only through continual experimentation toward improvement at the individual institutions that over-all progress will be made.

A detailed report on the conference is the subject of one session at the annual ASEE meeting at Pennsylvania State University in June.

The participants in the conference were:

Dean J. W. Buchta, University of Minnesota
Prof. J. W. Cell, North Carolina State College
Prof. P. F. Chenea, Purdue University
Prof. W. L. Collins, University of Illinois
Prof. J. P. Den Hartog, Massachusetts Institute of Technology
Dean H. Fletcher, Brigham Young University
Prof. N. Frank, Massachusetts Institute of Technology
Dean L. E. Grinter, University of Florida
Dr. G. H. Hickox, National Science Foundation
Dean E. Hutchisson, Case Institute of Technology
Dean R. B. Lindsay, Brown University
Prof. J. L. Meriam, University of California
Prof. Glenn Murphy, Iowa State College
Prof. M. S. Plesset, California Institute of Technology
Prof. J. J. Potter, Texas A and M
Prof. J. A. Sauer, Pennsylvania State University
Dr. Raymond Seeger, National Science Foundation
Prof. F. L. Singer, New York University
Prof. I. S. Sokolnikoff, University of Calif. at Los Angeles
Prof. W. B. Stiles, University of Alabama
Prof. D. Williams, Ohio State

Towards Improving Student Teacher Relationships

By F. D. EZEKIEL

Instructor in Mechanical Engineering, Massachusetts Institute of Technology

During the 1954 Spring Term a group of instructors and professors in the Mechanical Engineering Department got together for one hour a week with Dr. Harris, Psychiatrist of the Massachusetts Institute of Technology, to study and analyze the whole mechanism of teaching. The following represent some of the ideas that came to light during those meetings, plus some of my own personal experiences and findings.

During the very first meeting we uncovered the most important point. Before trying to improve our teaching methods and learn all about the students, Dr. Harris pointed out that it is of the utmost importance to look first of all into our own motivations in teaching. In other words, we have to study ourselves first. We have to ask ourselves the following questions: Why am I a teacher? Do I like teaching? What are my attitudes towards teaching, students, courses, etc.? What personal satisfaction or reward do I get out of teaching? What type of personality do I have? What are my weaknesses? Do I derive pleasure in imparting knowledge to others, flunking students, showing others how much I know, or acting as a supreme authority? Do I try to make my students happy? Do I arouse their enthusiasm, curiosity, and interest? Do I consider the students' feelings? Do I have the patience, tolerance and perseverance to deal with students? Am I teaching because I like to teach, because it is an easy profession, or because I am afraid to go out and seek another job?

The answers to these questions and many others help us to understand and possibly to solve some of the important problems involved in teaching. It is amazing how frequently we tend to blame the student for certain faults when we are really the ones at fault, because the student is only responding in his own way to what we have to offer.

After having acquired a clear and deep understanding of ourselves and our motivations, the next step is to learn as much as possible about the students. Here again it is imperative to ask ourselves some more questions: Who is the so-called student and what are his motivations? Is he here because he has the inward desire to learn, or is he here because his parents want him to study, or because going to college is the thing to do? Does he enjoy studying? How mature and responsible a person is he? Is every course to him another package of learning or another hurdle before his degree? Is he intelligent and capable enough to handle what we are offering him? What does he think of the teacher? How does he respond to him? Does he picture him as a person who is interested in helping him or another authoritarian like his father or uncle who has bossed him? Does he like or resent authority? Does he think the teacher to be honest and desirous of helping him pass the course, or tricky and seeking to fail him? How does he regard quizzes and grades? etc.

After having learned as much as possible about the student, the third step will naturally be to study the interaction between teacher and student. Inasmuch as people are basically different in many respects, it is rather difficult to set specific yet universal patterns of behavior that fit all instances. The best solution is to

study each case separately. However, since students in general do have a lot in common, there exist many similar types of interactions, and correspondingly similar successful methods of action on the teacher's part. The following are some of the points I found that help make teaching more effective.

Aside from the classroom teaching abilities and techniques, the most important element that determines the teacher's success and popularity is the type of relationships that he can establish between himself and his students. Students in general are extremely sensitive and therefore are more easily apt to form opinions about teachers that are very hard to change. It is during the very first few class periods that most of the attitudes are established.

Here Mr. Teacher walks in for the first time to tell his students how he proposes to run the course, how much quizzes and homework count, what he expects the student to do, and how he penalizes and punishes. Mr. Authority himself! The student reacts to this in various ways. He may take up the attitude of wait and see, or he may feel this is another authority in his life like his older brother, for example, and will immediately then transfer all his attitudes, defense mechanisms, and resentments, which he had developed earlier, to his new teacher. He may like him, hate him, or be completely indifferent. These initial opinions may change depending on how the teacher answers his questions in class, helps him in his homework difficulties, or even grades his quizzes. Accordingly, the student's class attendance, enthusiasm to study and successfulness on quizzes are at least partially dependent on how he feels towards the teacher.

Thus, the student-teacher personal relationship is extremely important for successful teaching. As a consequence, the teacher always must be careful when dealing with students. He must strive to keep his students happy and make them like him as much as possible, especially the students whose grades fall on the lower half of the scale. A student's pride can be injured very easily and unintentionally. For example, when a student asks a relatively simple question to which he is supposed to know the answer, the teacher may easily hurt the student's feelings by consciously or unconsciously ridiculing him. In most cases, it will be the last time that particular student will ask that teacher a question. As a result, he will resent the teacher and let other problems ride and, as a consequence, may fail the course.

To cite another example, when a student having felt cheated on his quiz grade, comes to see his teacher, the latter may spend a long time telling the student how carefully he graded all the other quizzes and how unfair it would be to change any grade. What will the student's reaction be? He is likely to think the teacher to be a block of concrete, tough and unyielding. He most likely will refrain from coming to see the teacher, not only with future problems with quiz grades, but also for any other problem. This has happened all too frequently—the student's personal relationship with his teacher is shattered. On the other hand, assume that the teacher takes an "easy-going" attitude. He gives the student the impression that he is ready to change his grade if a good argument can be presented, that he is thereby willing to give him the benefit of the doubt. What will happen? The student walks away happy with a sense that his teacher is an understanding man after all: if he manages to get an increase in the grade he will feel satisfied; if not, he at least gets the assurance that his teacher is a reasonable person to deal with. It is my own personal finding that, for the most part, this student will then spend more time in course preparation, and will as a result improve on the next quiz. In this way one can win the student's friendship and avoid being known as a "tough grader" or "slave driver."

Since a good student-teacher relationship is very much desired, the fourth step explores means of achieving it: by what

methods or schemes can you make friends with the sullen student, the one that thinks you are tough and tricky, the one who pictures you as a cruel authoritarian or the silent one who does not dare talk to you? The solution is simple. Make a definite appointment with the student to come to see you in your office. Once together, start asking him some simple questions in order to encourage him to talk to you. Be kind and gentle with him and above all, a good listener. The student, given his chance, will talk. Let him speak about anything. By so doing, the barrier that so often keeps people apart melts away. The student at ease will begin to think, "I have found a friend."

The importance of these words cannot be underestimated. This student will like and respect you. He will attend your classes and will study hard what you assign to him. In some cases he will even develop a great liking for your course and make it his field of specialization. You have inspired him and have become his friend. For example, a certain student I know failed his first term quiz and came to see me at my request. He told me all about himself, his family, and how his father sells lawn mowers. For fifteen minutes we talked thus. The quiz he failed was mentioned only in passing. We talked as friend to friend. On the next quiz he earned one of the highest grades and wound up the term with an "A" for the course. He wrote on his instructor evaluation sheet: "As a further indication of my pleasure with the teaching techniques, I have even attended many Friday classes despite the fact that I am home the preceding hour and have no classes following."

Another student who could be classified as sullen came to see me after obtaining the lowest grades on the two previous quizzes. It is not difficult to imagine why this student was not friendly. I gave him a chance to talk using every method I knew. After ten minutes he broke down and smiled, "Sir," he said, "I've got a block against you. I thought you were very tricky in that first quiz. When I took the second quiz, I was so nervous that I couldn't do anything. . . ." I then very briefly explained to him what my objective was in quizzing him and that I understood how he felt. By merely talking over his complaint, this student has discovered for himself my true attitude and hence has erased the conflict to save himself from a dangerous situation. From that day on, not only his class attendance and homework improved, but he obtained a relatively high grade on the next quiz and eventually passed the course. It is true this procedure is time-consuming especially on the teacher's part, but the results are unquestionably very worthwhile.

As regards effective classroom teaching techniques, it is very hard to outline any special ones since these are highly personal and dependent upon the personality of the individual teacher. However, I have found that enthusiasm on the teacher's part is of paramount importance. Creating an atmosphere of friendliness and warmth, establishing a relationship of confidence and fearlessness, having respect for the students, avoiding serious criticisms, offering challenges, keeping the class awake and attentive by asking suggestive, thought-provoking questions, and calling on students to take active part are effective tools. Generally, students tend to assume a highly passive mood during lectures and find it hard to change when exams come around. Encourage questions and discussions and respect everything that students ask. There are hundreds of students who don't dare ask questions to solve their difficulties for the simple reason that they are afraid to let the teacher and the other members of the class know how much they don't know. This is a great pity and can be solved. It largely depends on the teacher's attitude and motivations.

In conclusion, it seems to me that teaching methods can be improved and it is entirely up to the teachers to do it. If students fail, it is not wholly their fault. Many an unhappy situation can be avoided if the proper action is taken at the right time.

• • • YET-ITUDES

• *yelps and helps for the young engineering teacher*

Contributed by CYET
PHIL WEINBERG, *Chairman*
University of Utah

LEE HARRISBERGER
Editor of YET-itudes
N. C. State College

"The Uneagered Beaver"

At the beginning of his career in teaching every YET has to some degree an ambition to do a better, more unique job of teaching engineering. This is only natural because there is no one who has more faith in himself than the man who hasn't tested his power. This is motivator No. 1. The second big motivating force is inexperience. The YET wants to jump in feet first and try something because he is too "green" to know it can't be done. Consequently, he experiments with his teaching. He tries many things that have been tried by others, makes mistakes, goes up blind alleys, and finds out that some of the things the old timers have told him are true. But, he's trying.

If there were no experimenting, no one would know what would work and what wouldn't. Experience is knowledge gained from "trying it out." Progress is making mistakes.

But, there aren't enoughs YETs making mistakes. The natural inclination of the YET to "mix-it-up" in his work is too often squelched too soon in his career. The JOURNAL is full of theory articles but it doesn't often get to report the results of a brave soul's attempt at trying out the theory. There is little encouragement to strive for better methods. It is too easy for the YET to degenerate to a level of unconcerned complaceny—to become a victim of habitual doing. Even the more determined "eager beavers" find pioneering to be a futile task and give it up.

We looked around to see what were some of the things that "stall out" the eager YET. Furinstanz:

- There seems to be quite a bit of pressure from the old timers to have the course taught their way—using the text they have adopted.
- The YET is all too often given too large a teaching load. In any case he has too much teaching to do for a beginner. There is so much routine he can't possibly do anything else but teach it the way it has already been set up.
- The YET is pressured to do research and advanced study on top of his all-too-large teaching load. He is rarely encouraged to do research in the development of the laboratory or course he's teaching.
- The YET has to face the devastating inertia of an engineering faculty body. [This is a group of faculty people who are individually "for it" and collectively "against it." Status quo is its motto—altho it can't agree on what is the status to be quo about.] Here is where the YET learns to put educational problems last and professional problems first.

- There is one thing that "saves-the-day" for all present methods of teaching and tends to belittle any effort to make improvements. This is the fact that no one can prove that a school or individual's teaching program is inferior or superior. Thus, if your catalog checks with his pretty well, you're doing a good job.

All these frustrations "uneager-the-beaver." Teaching the course becomes an automatic habit and attentions are put elsewhere. Soon, he is even "bucking" a change because it would "shake-up" a comfortable teaching routine. It's amazing how a comfortable routine makes it right—tried and true!

It is too bad that engineering colleges aren't faced with a terrific competition to place their graduates. If competition existed to the extent it does in industry for the sale of the product, we would have no traditionalism and "status-quoism." If a school's graduates couldn't get hired because their training was inferior—there would be some real "hot" activity to revise the courses, invent new techniques of presentation, revise the curriculum, revamp the labs—jack up the faculty—get new texts, etc., etc.

In spite of all the discouragement that is presented to the YET who is moved to do some experimental teaching, some still try it and we slowly move ahead. We need more teachers to get in and "mix-it-up" in spite of the hostile environment. One of the best things that could happen to the teaching profession would be to have every YET revamp his course this next fall.

Throw out your notes and start from scratch—try a different emphasis—try a new technique! Rattle the old harness and shake off some of the dust! You'll find your work will be more interesting and you may even startle a few people. Who knows, you might do us all some good.—LH

* * *

Here's your YET-itude for June: Change it! Even if it's wrong! Progress was never made standing still!

ANNUAL MEETING

June 25-29, 1956

Iowa State College

Ames Iowa

Are Graduate Courses Millstones or Milestones?*

By L. L. OTTO

Professor of Mechanical Engineering, Michigan State College

Practically all of the engineering teachers who are now teaching graduate courses have worked their way up to that position by serving an apprenticeship at the undergraduate level. The usual pattern of a new entrant into the teaching profession includes a period as an instructor in one or more sections of a many-sectioned course where he may profit by association with older, more-experienced teachers in the same course, followed by a period in which he is given jurisdiction over and responsibility for a course or series of related courses. After this training period he reaches the point at which his teaching experience, his greater maturity in the general field of teaching, and his broad acquaintance with theory and application in a given engineering field, qualify him as capable of teaching graduate courses in that field.

If, after reaching this advanced attainment level he establishes or takes over a successful graduate course or courses he should feel that he has passed a milestone in his career as an engineering teacher, and in his value to the school for which he serves.

The co-existence of graduate and undergraduate courses in an engineering college gives rise to many advantages, both tangible and intangible, and to a few minor disadvantages. There is no other comparable way in which a young engineering graduate who aspires to become an engineering teacher can simultaneously earn the advanced degrees which the teaching profession presently demands of its members, and also come into intimate contact with the teaching methods used by the leading practitioners of the teaching art in its engineering phases. The close contact usually afforded by smaller graduate-course registration gives the professor a better oportunity to evaluate the possible teaching aptitude of the graduate student. If, by good fortune, the student is also a graduate teaching assistant, both student and faculty have an excellent chance to observe and evaluate each other with beneficial results to both. The student has an opportunity to experience both the thrill of feeling a class respond to his efforts at leading their reasoning processes, and the responsibility of presenting a planned, progressive program for successive periods. This opportunity helps to separate the sheep from the goats. The half-hearted and undecided aspiring teacher is discouraged by the responsibility and its accompanying labor, whereas the able, conscientious teaching assistant takes these things in his stride and is strengthened in his intention to become a teacher. This early selection and elimination process is of great value to the schools and to the subsequent career of the student.

The less tangible benefits of co-existent graduate and undergraduate courses are nevertheless real to both students and faculty. The presence in the laboratories of advanced work is a stimulus to the undergraduate student by actually showing him that individual and advanced research can be carried on by

* Presented at the Annual Meeting of ASEE, Educational Methods Division, University of Illinois, June 15, 1954.

others trained in the same curriculum he is following. His interest in, and appreciation of his present work is heightened thereby. The presence on the blackboard from a preceding graduate class of advanced applications and extensions of principles which the senior undergraduate is just then beginning to understand may show in some small way the fact that there are things to learn beyond the Bachelor's degree, and that it might be to the senior's advantage to continue his education after graduation and advance in his learning processes as a graduate student, as an extension student, or on his own. If this thought could be instilled strongly into the minds of our senior undergraduates a great deal of benefit would have been done.

The preceding discussion would indicate that the development of an adequate group of graduate courses was a definite milestone to a school, and to the teacher who participates in these courses. Before drawing final conclusions on the subject, however, I wish to elaborate on the relationship which exists between graduate courses and the person who teaches them. During the years in which I have been involved in teaching graduate-level courses in engineering I have often tried to determine for myself the relationship between the effort required to present the course and the possible reward which might return to the teacher. I have tried to evaluate my own attitude with respect to graduate courses and also that of others with whom I have discussed this situation at various educational meetings in the east and midwest. Among college teachers I have observed an attitude toward the teaching of graduate courses which varies all the way from resentment toward the work involved in a graduate course up to gratitude for the oportunity to teach a course at an advanced level to students who are really interested in what the teacher has to offer.

Personally I feel that anyone who is to make a success of graduate teaching must have an attitude toward these courses which lies at the latter extreme. For his own good, and for the good of his students he should honestly feel that graduate teaching represents an opportunity for him to be of real service to a selected group of superior students, to his own career, and to the school at which he teaches. If this is his attitude the work involved in preparing material which will hold the interest of the superior students will be accepted as necessary and desirable, and laborious though it may be it will never become a chore.

If the teacher's attitude is one of resentment at the amount of work involved in a graduate course, he might better be relegated to the teaching of less important courses, or in extreme cases to be eased out of teaching entirely.

Ample Fund of Enthusiasm Necessary

The benefit from graduate courses which accrues to the teacher and to the student is almost in direct proportion to the enthusiasm which the teacher puts into the course. Enthusiasm is contagious, it can be transmitted from teacher to student, and vice versa, to the mutual benefit of both.

The amount of effort required on the part of the teacher to carry on a graduate course program varies tremendously. Some teachers are fortunate enough to have handed to them a ready made program which someone else has built up into a popular or necessary course sequence, and for which adequate text material is readily available. In these fortunate circumstances the teacher needs only to bring to the course a thorough knowledge of the course material and its relation to other courses, and an ample fund of enthusiasm to rub off on the students. If this is done carefully the course should remain popular and be counted as part of the regular teaching load of its instructor.

Unfortunately this situation does not

always occur, and some teachers find themselves faced with a tremendous problem in their attempts to establish a graduate course or sequence of courses. To begin with there may be only a few graduate students at the school who have the necessary prerequisites and field of interest. Unless he can persuade all of these students, and possibly some others in addition, to take the course for credit during the same term, the number registered for the course will be below the required minimum, and he will get no credit on his teaching load for all the work he will have to do. Also there may be no suitable textbook available for the material he desires to cover, and he will have to supply the necessary information from his own notes and writings. This is almost equivalent to the writing the textbook and teaching the course simultaneously. Under these conditions even the best and most enthusiastic teacher, when harassed by committee assignments, building plans, personnel problems, and a heavy teaching load, will sometimes question the advisability of carrying on a graduate program in the face of such odds.

The fact that many teachers do struggle on against just such difficulties must in itself provide sufficient evidence that the opoprtunity to teach graduate courses is considered desirable. Graduate courses offer some things which the required undergraduate courses cannot offer. Most graduate courses are elective in nature and are taken only by students with special interests in the material covered by the course. In addition to this special motivation the graduate student usually has a better background in math, mechanics, thermodynamics, and related subjects, and is emotionally more mature than the undergraduate, so he will undertake successfully the more advanced and interesting phases of a subject which the undergraduate will not even attempt.

Furthermore a graduate course in most fields of engineering gives a teacher an opportunity to present to a critical but sympathetic audience any new material or new techniques which he has developed, and to obtain an audience reaction to his presentation at a time when any necessary corrective measures may be easily taken.

Last but not least is the opportunity to train the men who must take over the assignment of teaching future generations when he is ready to pass along that responsibility, and to repay in some measure the debt which he owes to previous professors who guided his own early graduate days.

Any of us who look upon graduate courses as a necessary evil, to be endured like any other required chore, have lost sight of the human benefits which can be gained from them. Unlike those people who expect to obtain their reward after they reach heaven, the teacher of a successful graduate course can obtain this satisfaction by observing with pride the progress of the boys he helped to train, and enjoying the warm friendships created in the process. Such a teacher will look back on his progression to the field of graduate courses as the opening of an opportunity, and the question of millstones versus milestones will have received its proper answer.

Education for Creativity in Engineering

(with the aid of six pairs of I's)

By M. S. GJESDAHL

Professor of Mechanical Engineering, Pennsylvania State University

Recently a newspaper article appeared outlining the educational steps involved in teaching creativity in art among young children in elementary schools. The article stated that it was deplorable for a proud father to buy coloring books for his youngster because this left no incentive or ingenuity to be supplied. Great strides are being made in creativity in art with youngsters.

Likewise, in home economics education, the student is encouraged to be creative, original and distinctive, in design and styling as applied to feminine attire. The results of effort in creativity are often quite revealing.

Inventive technique or creativity in engineering is possible without formal training. We are now trying to formalize the pattern or technique which has been practiced by individuals who had a limited amount of education and who developed successful procedures for creativity. Thomas Alva Edison concentrated his time and effort on the *development* of an idea which his mental curiosity had aroused and which his mental habit would not allow to become dormant. His formal education was interrupted at an early age yet he trained himself in creativity by study, experimenting and an insatiable desire to solve a problem and make it work. Likewise Charles F. Kettering failed to complete his academic career in engineering. He, too, developed a philosophy and an approach to problems, particularly in the automotive industry.

In recent years several large companies have instituted programs which train in creative thinking. The General Electric Company is well known for its Creative Engineering Program. In these programs young engineers are encouraged to develop their capacity for the solution of problems or projects which may be new, which may have been tried before and given up, or which somebody said could not be done.

Sometimes age is unnecessarily effective in diluting enthusiasm. As Alex F. Osborn, an advertising executive, and author of an excellent book entitled, "Applied Imagination," says, "Older leaders must especially guard against letting their long experience make them cynical toward ideas which might seem unpromising at first blush. So warns Clarence Francis, head of General Foods: 'Younger executives come to me with what they think are new ideas. Out of my experience I could tell them why their ideas will not succeed. Instead of talking them out of their ideas, I have suggested that they be tried out in test areas in order to minimize losses. The joke of it is that half the time these youthful ideas, which I might have nipped in the bud, turn out either to be successful or to lead to other ideas that are successful. The point I have overlooked was that while the idea was not new, the conditions under which the idea was to be carried out were materially different.' "

One of the basic requirements for consideration of Education for Creativity is an unhibited mind. How often it is noted that an individual untrained in the sciences and engineering asks the

searching question, "Why doesn't somebody develop a method or a gadget to do thus and so?" Right there is an idea for creativity. A need has been suggested.

Engineering education, in the final analysis, is dependent to a large degree upon the developments of the past and the experience and academic training of those who teach. Many industries, in recent years, have requested engineering faculty members to render assistance on problems for which their own engineers do not have time or are incapable of solving. The approach to an unusual problem, which the instructor uses, is the approach which students in engineering need to learn something about.

It is possible by dint of hard work (which is required) to develop techniques in creativity by individual effort. However, companies obtain fruitful results by group effort concentrating thought on a project or program. The suggestion box in a manufacturing plant is an example of encouraged group effort.

Developing Creative Ability

What factors are important in developing creative ability? The mental processes in proceeding from the known are fundamental in scientific training. Combined with an insatiable curiosity and imagination, acquired academic knowledge leads to development along new paths. A sense of dissatisfaction with routine procedure is helpful. Suppose this line of thought is applied to engineering education.

Let us assume that a group of students have a foundation of basic engineering education (if such a premise is valid) or rather let us assume our candidates are ready to begin their fourth year in engineering. Up to the present time, academically very little integration of the various courses in a curriculum has been evident. Facility in mathematics, an absorption of physical laws, a little dab of service courses in other curricula added to the main stem courses —and so we have fourth year students with a mental basketful of packaged courses. In another 32 weeks, these students are separated from the cloistered protection of prepared lesson assignments with known answers to many more or less carefully prepared problems. Fundamental, yes, but what inspiration for creativity exists in such a traditionally operated sequence of educational steps? Even our examinations are slanted toward a pattern solution because all answers should agree with our own to a certain decimal point.

In what way may the concept of creativity, imagination or inventiveness be applied in each course? As the fundamentals of descriptive geometry, mathematics, physics, mechanics are covered, is the main emphasis in these courses a question of quantity or efficiency of absorption at the close of an academic year? Do we conclude with a mental sponge more or less fully absorbed with droplets of engineering data in a metastable state, or have we developed a reservoir of fissionable material which requires only a state of unsettled impatience or ingenuity to gender a chain reaction resulting in a capacity for creativity or scientific development?

Practical Creativity

Mr. E. K. Von Fange of the General Electric Company has the following to say about college training. "The usual college training adversely affects creativity. For example, the assignments given in a typical engineering institution might be likened to a foot-bridge swinging and swaying across a rather wide and deep chasm. The problem is the bridge. At the other end of the bridge lies the solution. Strong and sturdy guide rails are formed by the detailed definition, boundary conditions, the applicable formulas or procedures given in the text, etc. As the student goes through his years of education, he is sent across progressively longer

bridges, though each is still adequately protected by guard rails, and he has little difficulty. Then, upon graduation, the guard rails are removed and he is told his sheepskin equips him well to start across the bridge. Small wonder that engineers, new to industry, are a bit hesitant and undecided about what to do and how to go about it! And small wonder, too, that they learn to use the safely guarded bridges of the conventional in their engineering career and refuse to cross a creative bridge even if they do see it, simply because it has no guard rails to lead and guide them."

For the past few years, in applied machine design with sixth semester juniors in mechanical engineering we have assigned a term problem, allowing about ten weeks of the total sixteen weeks on the problem. Last semester the problem involved the design of a dual-purpose electric motor driven impact tool for power screwdriving and for power hammering or chiselling. A combination tool of this sort is not on the market. The specifications among other items included a computation notebook showing the evolution of the tool design with all sketches made of proposed mechanisms and structural details whether or not they appear in the final design, all calculations made to justify sizes and proportions of the critical parts of the tool, and references from catalog literature indicating selection of commercially available parts. The final design was presented in a layout assembly drawing of the proposed power tool on 17 by 22 vellum paper. Sufficient views and sections to describe its external appearance as well as the internal construction and arrangement of parts were required.

During the last week of the semester each student was given an opportunity, in ten minutes, to describe his design to a panel of three instructors, one of whom was his own in the design course. Then, he was questioned by the panel and he was required to justify and clarify features which were ambiguous or erroneous. Each member of the panel evaluated the design on the basis of originality and presentation, engineering design and production.

The comment so often made by the students at the end of the semester is that they used much of their previous training and that they "were really on their own." The instructor serves as an advisor and encourages the exploration of an idea which the student offers in the design project. It is enlightening to the instructors who must consider design problems with the students. Of course, a few try to lean on the experience and judgment of the teacher. Self-reliance does not come easily to some.

Six Pairs of I's

In considering education for creativity, six pairs of I's seem to be basic. They may be applied by student and teacher alike.

Creative Thinking is a concatenation of three pairs of I's, that is, of Imagination and Ideas, Incentive and Initiative, and Illumination and Inspiration. The result of insight with I's such as these leads to Creativity through the other three pairs of I's, namely; Information and Intelligence, Investigation and Interpretation, and finally Invention and Improvement. The use of these six pairs of I's on any problem or project should yield, in appropriate time, a solution or result which may be said to be creative. The acquisition of, or the encouragement to get, an ability to think and act creatively is an important aim of education in engineering.

Suppose each one of us were given the problem of designing a safety device for refrigerators, the household type, so that a youngster who may have been shut inside by playmates could by some means unlatch the door. Try and apply the six pairs of I's to such a problem.

The August 1946 issue of *Mechanical Engineering* contained an article by Wil-

liam H. Easton entitled "Creative Thinking and How to Develop It." In this excellent article, among other important statements, he says, "There are three creative processes which are used by every thinker. These are: *Imagination,* which is the power that enables a thinker to weave ideas into new combinations while he is engaged in deliberate thinking. It usually deals with easily remembered ideas. *Inspiration,* which is the result of an accidental stimulus. It occurs when new ideas derived from some observed object or circumstance suddenly and automatically combine with old ideas. *Illumination,* which is evoked by intense deliberate thinking and forms new combinations of ideas after the thinking has ceased. It resembles inspiration in occurring without present effort, but has an entirely different cause. It frequently brings to the surface long-forgotten ideas." Note the I's in the quote just given.

In a sport, whether played singly or on a team, after we have learned the rules and rudiments of performance, we try to outmaneuver the opponent with imagination and the unexpected. Creativity is like that. It is trying the untried, asking why not, making assumptions—radical ones, using past experience and present needs to generate ideas. As in a game, it requires effort to win.

A high-grade cabinet maker became skillful because he first learned the proper use of his tools, so that each tool would perform in accordance with his designed effort. The fact that he is a high-grade cabinet maker is not due to his *possession* of the tools, but due to his ability to apply them as needed. His inspiration and ingenuity produce the difference between excellence and mediocrity.

Thus in training engineers though we may supply the necessary tools of the profession by our educational process, it is essential to instill that ingredient or spark which sharpens the imagination with the intellect.

In evaluating our perspective of engineering programs, our teaching techniques and integration of course content, it is our goal to develop well-prepared, confident, inspired, *creative* young engineers. Of such, there is a great need.

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The Education of Leaders*

By ROBERT B. DAVIS

Assistant Professor of Mathematics, University of New Hampshire

Sometimes philosophy is important.

I have seen students required to take courses which are worthless to them. This, unfortunately, *does* happen, and often on rather a large scale. It is defended by saying that the course has always been required, or prehaps it is defended by saying that *many* students need the course, or perhaps it is defended by saying that one must learn trigonometry quite thoroughly before one is prepared to go on to calculus. I have heard courses in analytic geometry defended by the statement that they are "not without interest."

All this is a question of judgment, and it is often hard to put one's finger on the root of the matter. In any question of judgment, we need to know all of the facts. It does not do to dispense judgment at a distance, and one has to be careful not to talk in empty generalities.

Nonetheless, in a precise, concrete way, making due allowance for the delicate judgment involved, I find that I am shocked at some of the philosophy which I have encountered in academic circles.

There is the philosophy of uniformity. We must treat everyone *exactly the same.* Not fairly. We cannot treat everyone fairly if we are to treat everyone the same, because students are not identical when they come to us, when they register for our first-term freshman courses. The one student knows trigonometry well. The next does not. The one is eager, the next is lazy.

But I have frequently heard faculty members say that we must treat everyone the same. And they meant exactly that! This student got a 59 in our course, and so did that one. We *must* treat them the same. No matter that student A has been out of school for years, has never had a strong high school background, has worked hard all term, has been hampered by the illness of his wife, but nonetheless shows unmistakable signs of the maturity and good judgment which promise to make him a good civil engineer, let's say. No matter that student B came with a good background of factual knowledge, refused to believe that there was anything he did not already know, and in fact finally stopped attending class altogether. No matter that student A made nearly 60 in every quiz all term, while student B's record began with 90's and ended with zeros. They both ended up with an average of 59! Treat them both the same! For both diseases we have the single remedy: students A and B will repeat the course next term!

No matter that, as a civil engineer, student A will not really require this course in his later professional work, whereas student B, in his work, will.

I know perfectly well where this philosophy of uniformity comes from. It is the offspring of another pernicious idea: the idea that we must avoid criticism above all else. Like the politician who prefers doing nothing, because doing anything at all will create some enemies, we faculty members often act as if we are quite prepared to see our curriculum become outdated, rather than risk criticism. If we do this year what we did last year, we shall have a precedent, and

* This paper won second prize in the 1954 Y.E.T. contest.

a precedent, in academic circles, is the best possible answer to criticism. Logically it is an unacceptable answer altogether: a precedent, logically, means that either one was making the same mistake already last year, or else, perhaps, one is refusing to seek improvement or even to keep abreast of change. But *de facto* it is the best answer of all. Just say: "Why, we have *always* done it that way!"

I think we must be willing to experiment, and at a good rate, too. We cannot sit in last year's ivory tower and concentrate on avoiding criticism.

Let me return to the required courses which I mentioned earlier:

Does one learn trigonometry thoroughly, and *then* learn calculus? I say emphatically one does not. No student who has just completed a course in trigonometry for the first time is already the complete master of the subject. *Working with* trigonometry, subsequently, is what drives it home. Yet we often divide the curriculum into vertical segments with far too much separation, and require an unrealistic degree of mastery at each step before allowing the student access to the next higher step in the ladder.

We also divide the curriculum into horizontal segments, and teach—for one example—integration as a dull (and difficult) mathematical technique, where the practically-minded student finds little to seize hold of. We teach differential equations as a separate subject. The study of beam bending is again separate. Yet these three areas can be effectively combined, in a certain sense. Not necessarily that the three courses should be replaced by one. There is too much material in them for that to be possible. But combination of a sort is possible and extremely effective.

One can walk into a class in Integral Calculus, and ask the question: if a beam is to be loaded uniformly, will we be less in danger of breakage if the ends are rigidly fastened, or if they are free to pivot? I know how well this type of integration can work ("integration," that is, in the sense of tieing subject matter together, not in the sense of un-differentiating a differential), because I have tried it. I have asked precisely this question, to a class of students armed only with their Integral Calculus texts. Some of the problems at the end of the chapter, in the text, contained all the theory that was needed.

And the technique worked magnificently!

The students had expected me to come in and spend the period evaluating integrals like

$$\int \cos^4 x \sin^4 x \, dx.$$

They expected me to stand there and write formulas all over the blackboard while they waited impatiently for the end of the hour. They were quite excited by the idea that simple reality questions had a proper place in a "dull" math course. Moreover, I am sure that they were excited by the idea that I could treat them as engineers, and ask a simple question, leaving to them the task of locating the proper section in the text, leaving to them the problem of achieving a suitable mathematical formulation, and leaving to them the proper interpretation of the mathematical result.

Frankly I am proud of that episode. Because it was much more than one hour's work. If I had not prepared a suitable atmosphere earlier in the course, if I had not shown the students that I had confidence in their ability to get along with a minimum of help from me, the result would have been dismal, not triumphant. I would have asked the question . . .

. . . and the room would have been filled with a beautiful, tranquil silence, but no sound whatever of an answer.

Dependent Relationship

I have another class, on a more advanced level, where it is much more difficult for me to persuade the class to give up their passive dependence on me. Of course I want them to feel that I am there ready to help them, at any time when I am actually needed. But I want them to learn that they can get on without me. I want them to know that I have confidence in them, and that I am not indispensable. And I want them to learn confidence in themselves. We have made progress in this class, these students and I, but there is still a long way for us to go. The students are beginning to believe that my confidence in them is genuine, but they are still somewhat uncertain whether or not they deserve it. We shall have to show that they do.

This is a very delicate area. It is not a trivial question, the proper handling of the student's dependence. The student must get support from the teacher, but he must learn to stand on his own two feet out of the simple joy of doing it. He must come to stand on his own feet because he really wants to—not because he has been thoughtlessly pushed into such a posture.

In handling this dependent relationship, the teacher is called upon to display the delicate skill of a surgeon—and not the all-too-frequent technique of a pedagogical butcher.

Let me list some more philosophies which I think are dangerously false:

False Philosophy No. 317: The students must be told exactly what to do, how to do it, when to do it, and—afterwards—how well they have done it.

(I say NO, four times!)

False Philosophy No. 321-D: Education is like medicine; if it isn't unpleasant, it isn't really doing much good.

(On this I carefully refrain from making comment, in order not to depart from the generally discreet tone of the present communication.)

False Philosophy No. 407-XHF: Industry wants obedient engineers.

(I say . . .Oh, excuse me. Let's just say: "Industry, as nearly as I can tell, does not want men who expect to be told what to do and how and when to do it. Industry wants men with initiative . . .

. . . that means men who *decide* for themselves, who can act on their own decisions—and, of course, men who get along well with others, who cooperate in organizational manoeuvers, who see things in context—men who will see the possibilities inherent in something new—men for whom the future is something exciting and different . . .

. . . and you don't train men like that by telling them what to do for four years. You don't train men like that unless you, as their teacher, are pleased to regard yourself as just barely necessary—not indispensable—and are honestly convinced that, as students, they *can* do things by themselves. You have to respect their judgment, and you have to recognize and respect their motivation.)

Initiative is never going to line up and get a serial number, and you can't train it that way, either. That way, you can only kill it before it even gets started.

Let me, finally, return once more to our earlier discussion of required courses. Why is analytic geometry required? Its subject matter is so intermingled with that of calculus, and with the elementary notions of vector analysis, that a much smoother "unified" course can be created, instead of teaching all of these subjects separately. In doing so one leaves out, to be sure, certain highly specialized topics in analytic geometry. These omitted topics, however, are almost never useful. It is true that in studying them, the student does get some additional training in mathematical manipulation, which is of course valuable. I admit that, but . . .

. . . But aren't we also, in analytic

geometry courses, teaching the student that mathematics is a dull and difficult game which has little to do with reality?

This notion is widely held among engineers. It is untrue. Yet it must come from somewhere. I would say that it comes from the *organization* of our mathematical curriculum, from the *way* in which math is presented, from the unfortunate separation which we make, between math and the other engineering and science courses. Even the physicist, who ought to be working hand in hand with the mathematician, tends to regard the mathematician as someone vaguely impractical, more concerned with formalisms than with practical accomplishments. How are we to bring the curriculum back together again?

If we want to teach the student some mathematical technique, is it not better to teach him the manipulation of mathematical materials which are still alive, rather than the dried-up, desiccated particularities of many analytic geometry courses? Who cares what a *latus rectum* is? The *standard deviation* would be more to the point.

We could eliminate analytic geometry, move the courses forward, and make room for a better course in differential equations, or for a course in Bessel functions and partial differential equations arising in engineering, or a course in numerical and graphical methods, or perhaps even a good course in probability and statistics.

This would be exciting material. And one could make sure that such a course was generously sprinkled with current engineering applications that would help the student to tie his entire education a bit more closely together.

And, of course, the mastery of manipulation would still be present, just as much so as in analytic geometry.

Although I shall not dwell on it, this is in fact another question of philosophy. When someone says "this course is not without value," I find myself thinking:

"Yes, but what else might be better?"

I think the universities need to cultivate a greater realization that they deal in an economy of scarce means. There are just so many class hours available, just so many rooms and so many teachers, just so many years in the students' lives, just so much mental effort per student. Not an unlimited amount of time, nor an unlimited amount of mental effort. We *say* that we recognize this. But do we, when our curriculum includes the *latus rectum* of analytic geometry, with no apparent awareness of all the more important material which is being left out?

Please do not misunderstand me. I do not refer only to analytic geometry. I refer to all of the material of secondary interest which is permitted to fill our curricula, excluding material of primary interest. We are well able to see the exclusion principle in quantum mechanics. Why can't we see it in our university curricula?

I refer to all of the special *little* items that have excluded more important *general* questions. Analytic geometry is merely one case in point.

And since we have said that philosophy is important, I wish I could find, also, the proper way to ask the following question. I would like to ask every teacher who leads the student every step of the way, who feels the student could not make it by himself, this:

"Why?"

"Why do you think the student incapable of getting along by himself? He can organize his own clubs, can't he? When he goes astray, a youth can organize a band of others, and devise all manner of nefarious activity, much of it highly ingenious. Students can learn subjects, such as electronics or music or the art of writing short stories, entirely by themselves, in their spare time, if the fancy hits them. Why, then, do you feel that students must be led

carefully along? I say that the job of the teacher is to inspire the student, then let him go by himself."

It seems to me that the teacher who leads every step of the way is afraid. He is afraid that the student will be able to go on without him.

Or perhaps such a teacher is just lazy. It is so easy to lecture to one's audience (Merciful Heavens! Am I doing that in this article?), without admitting that *the audience* (a phrase which sounds impersonal) is actually a group of fifteen or twenty human beings, each of them quite different from all of the others, each of them having feelings, passing judgments, making decisions, and acting on their own (even if their only decision is to cut class as often as they can.) Is the teacher who delivers dull, routine, rote lectures really *aware* of these twenty human beings, and of all the potentialities within each of them? Is he permitting himself to recognize the myriad complexities of their various futures? All of the things they will do, or will fail to do, during the next fifty or sixty years or so?

Why on earth do teachers want to be textbooks?

Conclusion

It seems to me that all of us who are faculty members need to work honestly —and with some definite determination —to create and maintain a certain desirable atmosphere in our schools. An atmosphere, that is, that aims at training leaders, not meekly submissive robots; an atmosphere that sees the teacher as someone who is there to help, not to threaten or to criticize; an atmosphere that respects the student's ability to think for himself; an atmosphere that is lively and changing, that views a new and different tomorrow as a thing of exciting promise, not a dangerous departure from the dull repetitions of all of our yesterdays. An atmosphere, that is, of science, creativity, maturity, and emotional warmth.

An atmosphere, that is to say, of happiness, growth, and progress.

Acknowledgement to National Science Foundation

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Unionization of Engineers—A Reexamination

By GLENN W. MILLER

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In the December, 1954, issue of this Journal two authors took a very strong position to the effect that professional behavior and attitudes to be expected of engineers are incompatible with membership in a union. Mr. Clarence T. Shock and Mr. A. A. K. Booth approached the subject from different angles but arrived at much the same conclusion. Both discussions are founded on value judgments as to the motivation and behavior of union members. However, many of these concepts seem to spring from the atypical (but well publicized) actions of some unions and unionists. These ideas merit further examination if those who read the Journal wish to examine all sides of the question of unionization of engineers.

Early in his discussion Mr. Shock refers to "the philosophy . . . of collective bargaining" and comments immediately that "the words have a sinister sound to us, and portend a situation in engineering circles totally foreign to the generally accepted philosophy of a professional man." It is to be presumed that the sinister sound heard by Mr. Shock echoed from the word "bargaining" rather than from the word "collective." Mr. Shock wrote as an officer of an engineering society; the very existence of such a society indicates action by the group (i.e., collective action) to achieve certain agreed upon goals. Evidently there is a line to be drawn between the activities in which engineers (and other professionals) may engage collectively and those actions still in the preserve of individual action. The question is where this line of demarcation shall be drawn.

The writer would be the last to suggest any weakening of an attitude of genuine professionalism within any group. However, it seems that the ego-satisfaction that may come from membership in a relatively small, elite group often is mistaken for professionalism. Along with a skill or ability possessed by relatively few, professionalism carries with it a certain philosophy which is "fundamentally eulogistic." * Both the search for ego-satisfaction and the eulogizing of the profession are pseudo-professionalism to be contrasted with the genuine professionalism which is characterized by competence in a chosen field, intellectual curiosity, and willingness to devote much time and effort in the use of one's special abilities for the improvement of society. Perhaps this tendency to eulogize the profession is one of the most important factors creating the philosophical breach between many "professionals" and "labor." As long as the professional considers himself in a group apart (and also fails to understand more about organized labor) then techniques that may be used by large numbers probably will not be accepted.

Not all professional groups hold the opinion that union membership contradicts professionalism. Musicians, actors, and newspaper reporters, are examples. Air line pilots have their own union that bargains collectively. Engineers may argue that the examples cited are not professionals to the same degree that they (the engineers) are. However, the eulogistic philosophy of the professional

* Northrup, H. R., "Industrial Relations with Professional Workers," Harvard Business Review, Vol. XXVI, No. 5, September, 1948, p. 543.

should be kept in mind. The reporter, musician, or pilot will be able to argue the peculiar importance, and professionalism, of his job. Even so, many of them have turned to collective economic action.

Mr. Shock is of the opinion that "our immediate problem really has little to do with employers or employees as such." Evidently in his point of view engineering employees stand alongside management pursuing similar goals along the same paths. From this point of view flows the attitude that an organization of engineering employees to pursue the goals of employees is indefensible. Taking as his *bete noir* the Engineers and Scientists of America, he states "we are apprehensive . . . of the stated aims and objectives of this organization, which are at extreme variance with the more altruistic motives expressed by the long established professional engineering societies." Subsequently, he expresses his bewilderment "how has the engineering profession been maneuvred into this peculiarly contradictory situation of professing on the one hand to devote its combined talents to the benefit of mankind, and on the other, to foster activities which are extremely controversial as to their public interest value?"

This apprehension and perplexity is unwarranted. Any form of behavior can be found in the labor movement of the United States. A person can find examples to emphasize his greatest fear or to support his most optimistic viewpoint. Much depends on what the observer wants to see. The labor movement in the United States is some 150 years old and 17,000,000 strong. Taken as a whole it has a proud history; it has been in the forefront of the struggles for many of the social and political institutions that we enjoy now such as free public schools, abolition of imprisonment for debt, child labor legislation, social security measures, minimum wage laws and the like. Indeed organized labor has been one of the strong and consistent supporters of the democratic way of life.† While there is no doubt that Mr. Shock and others can find examples of union behavior to bolster their fears, examples which the bulk of the labor movement itself decries, the typical behavior of unions is quite a different story.

Strike Activities

Engineers are disturbed by the potentiality of strikes and other coercive activities of unions. Mr. Shock refers to "the usual methods of unions (coercion, strikes, picketing, closed shop, etc.)" Mr. Booth notes with disapproval the strike action of one group of engineers. Again the misgivings are not well-founded. In industries covered by the Taft-Hartley Act, the closed shop has been unlawful for nearly eight years, so it hardly merits the adjective "usual." As for strikes they are not a usual method. In only two years in our history have the numbers of workers engaged in strikes exceeded 3,500,000; post World War II years show an average of fewer than 3,000,000 strikers. These figures may be compared with a labor force now totalling nearly 65,000,000 and a union membership of about 17,000,000. In most years the percentage of estimated working time lost because of strikes is less than one-half of one percent.‡ Engineers seem especially to decry the strike weapon. While their reasons may be different, most workers also are opposed to striking if it possibly can be avoided. Strikes cost individual members who are involved and unions large sums of money; they are embarked upon reluctantly. The publicity given to labor disputes and the little attention paid to peaceful labor relations has done much to

† Millis, H. A., and Montgomery, R. E., "Organized Labor," McGraw-Hill Book Co., New York, 1945, Chs. I through V. See also Dankert, C. E., "Contemporary Unionism in the United States," New York, Prentice-Hall, Inc., 1948, passim.

‡ For current data on work stoppages see *Monthly Labor Review* issued monthly by the U. S. Department of Labor.

foster an erroneous impression of the inclination of unions and their members to strike.

Still another comment is relevant to the strike fears of engineers. It is almost unheard of for a strike to be called just to create excitement, to harm or destroy an employer, or for any such type of reason. A work stoppage occurs when workers and management can not agree on terms or conditions of employment. Let us take a very simple example. A union asks an employer to pay $2.00 per hour for a certain type of labor; the employer will offer no more than $1.85 and a work stoppage ensues. Both parties want work to continue—under the conditions that they are backing. Strictly speaking there is a *strike* against working at $1.85 per hour and a *lockout* against work at $2.00 an hour; use of the term "strike" is unfortunate since the label suggests that the union is responsible.

Mr. Shock is of the opinion that "unionization places sole emphasis on wages and hours, and on union membership." Probably unions always will put considerable attention and effort on the subjects mentioned. However, to imply that the "sole emphasis" is as suggested is to ignore many problems on which unions spend much time. Representing workers in the handling of grievances, working on problems of health and safety, negotiating on subjects such as vacations and sick leave are only a few examples of the many issues beyond wages, hours, and membership in which unions are interested. Some activities of unions today go well beyond the work-place and into the communities in which we live.

Many of the activities of present-day unions are not of primary benefit to their own members. Support of a minimum wage law will be an aid to workers with low incomes who are likely to be unorganized. Support of a United Appeals campaign or a blood donor program are other examples. Standing squarely behind the philosophy of intellectual freedom when it is threatened in a college or university takes union organizations still farther afield. The list of such "extracurricular" actions of unions could be expanded greatly.

Most engineers are inclined toward a pro-management point of view. Since World War II the writer has conducted two or three classes each year in labor problems for engineering students; their pro-management attitude is clear, although they do not differ greatly in this respect from other university students. Messrs. Shock and Booth strongly support this management orientation. Arising from this attitude, there is a reluctance to think of engineers as employees.

Recent studies (not centered on engineers, it is true) suggest clearly that union membership does not destroy loyalty to the employer.§ There is no reason why the engineer who chooses to join a union cannot remain loyal to the company and continue to command the trust and respect of management. Most of us have multiple loyalties—perhaps to family, church, lodge, friends, professional groups, unions, employers, political parties, and the like. The motivations and goals of such groups will not coincide always, and choices will have to be made. But membership in one group or association does not necessitate disloyalty to some other institution whose aims or goals may be somewhat different. It may call for accommodation or compromise, but such is life. The aims of management and employees may diverge (especially in the short run) but they are not unalterably opposed. Satisfactory working arrangements can be and are worked out day after day.

Employee Status of Engineers

As to the employee status of engineers, the American Federation of Technical

§ Purcell, T. V., "The Worker Speaks His Mind on Company and Union," Cambridge, Harvard University Press, 1953. See also "Dual Allegiance to Union and Management" (A symposium), University of Illinois Bulletin, Vol. 51, No. 79, July, 1954.

Engineers (A.F. of L.) comments "in America today, over 90 per cent of all technically trained persons are employed on a salary basis. . . . This condition is the result of the transition of industry from single ownership to the corporate type of collective ownership. This growth of industry has directly affected the status of the engineer. . . . It has created the Employee-Engineer." ‖

If the typical engineer is an employee, will the type of professional organization used by some other groups meet the needs of engineers? Mr. Booth cites with approval a speech delivered before a branch of the medical profession, and wishes for the same type of professionalism among engineers. It is true that doctors and lawyers affect their economic status through "professional" organizations. However, most doctors work for themselves selling services directly to the public. The economic relationship of a doctor or lawyer to his patient or client is quite different from an employer-employee relationship. In the first place, little bargaining occurs over the price of medical care. If any kind of bargaining were to occur the doctor will be the equal or better of his "employe" or patient; he needs no union to deal for him. Logically he will pattern his group activity after those of the business man. A "trade association" type of group activity may serve adequately the economic interests of the group. On the other hand, employees may need a different kind of organization to serve their economic needs—if they decide that these needs can not be served adequately by their individual efforts.

If groups of engineers were to elect to organize, there is no reason to assume that bargaining done on their behalf would be identical with that of any other union. The issues bargained out and the techniques used vary widely from union to union, depending on the membership and leadership of the union, the attitude of the employers, the problems of the employee group, and the like. George Meany, President of the American Federation of Labor, commented recently on some of the misgivings of engineers regarding unionization: "No other organization or union has any voice in formulating the collective bargaining demands of the American Federation of Technical Engineers, nor are the wage and salary rates for members . . . patterned after the rates or contracts negotiated by any other union. The gains made . . . have not been accomplished at the expense of stifling initiative. . . . Patent rights of members are protected by articles in the contracts." ¶

Engineers themselves must decide on the manner in which they shall pursue their economic interests. Under present federal labor legislation they are free (as long as they conform to the vote of a majority of the bargaining unit) to unionize or stay out of unions. If they choose to unionize, they may do so in a separate group, as long as it is not employer dominated, or as a part of a union that includes employees other than engineers. The choice should not be made lightly, since it calls for a decision as to whether the past philosophy of economic individualism continues to be a desirable guidepost. All relevant information on the issue should be considered. This discussion suggests that, in the past, full and and unbiased information on unions often has been lacking. In making a decision it is suggested that the following propositions be considered as well as those expressed by Messrs. Shoch and Booth:

1. It is becoming increasingly difficult for the individual employee to control his economic life effectively. Opportunities for employment, advancement and the like are affected by many forces besides the efforts and desires of the individual, and beyond the control of the individual.

‖ "Are You Afflicted With Professional Aloofness?," recruiting leaflet issued by the union.

¶ Meany, George, "Engineers Need Unionism," *The American Federationist*, Vol. 62, No. 3, March, 1955, p. 20.

2. Engineers or other groups of professional employees probably will find that professional societies are inept and reticent at representing the economic needs of employees.
3. Many professional workers, engineers included, have joined unions. In most instances these unions have centered around persons of a certain technical or professional knowledge.
4. Membership in a union need not conflict with genuine professionalism although it may tend to reduce the degree of individualism assumed by some to be part and parcel of professionalism.
5. In general, unions do not act in a way that is contrary to the public interest. Examples to the contrary can be cited, but these are not representative of the union movement in the United States.
6. If unions could help engineers to become well-paid and relatively secure in their jobs and economic future, engineers need not lose any of their respect for their profession, their intellectual curiosity, nor their desire to serve in such a way as to build a better tomorrow.

This discussion draws no conclusion as to whether engineers should join unions; that decision is one for the engineers. It is clear, however, that many professionals have a meager and often erroneous impression of unionism in the U. S. today. This paper attempts to clarify some of these misconceptions held by many engineers.

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Some Suggested Changes and Shift of Emphasis in the Engineering Curriculum

By ERIC J. LINDAHL

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I, for one, would like to feel that the unified curriculum is just around the corner, and it may be for a few institutions, but until a great deal more selling work is done, I think it will be some time before the operation as now practiced in nearly all engineering colleges is abandoned. In the meantime we should look about carefully to see if we can make our present system more efficient by consolidating as many courses as possible and by taking the frills, the non-essentials and overlapping materials out of our present offerings. Only in this way can the four year program be salvaged since there is now no room to add courses and the addition of a new course comes at the expense of some course already in the curriculum. In the small schools, it is also imperative that we make use of our class rooms and instructional staff in a more efficient manner by putting students from several departments into one class as much as possible. If, by a wave of the hand, we can't have everybody taking the same thing, then perhaps a gradual change can be affected by gradual consolidation of the various programs that now exist.

One way to bring about consolidation is to do away with that unpopular thing called the engineering service course. I have found that almost universally these courses are unpopular and dreaded both by the student who takes the course and by the instructor who feels that he is forced to lower himself by teaching the course. The young instructor frequently is caused to teach the service courses and it is no wonder these young men sometimes wonder if they are in the wrong business.

It once fell to my lot to teach separate service courses in heat power for chemical engineers, for civil engineers and for industrial engineers. In each case the first few pages in the text were devoted to elementary thermodynamic equations which were presented in such a sketchy fashion that the poor fellows were left hopelessly confused and bewildered because otherwise worthwhile material received such a "lick and promise" treatment. Certainly they had nothing upon which to build in later years and in my estimation if a course presented in an engineering college cannot be used as a foundation for future study then that course is to be considered useless.

I would suggest that rather than being required to take the special service course, that the students in the other departments take all or part of the same course as the students for which that course is a major.

For one thing I would suggest that all students take the same course in thermodynamics as that which the mechanical engineers are required to take. While it is true that, while there will not be so much application material in this course, that which they do learn they will learn more thoroughly and they will have a foundation upon which to build.

The same is true with mechanical engineers and others taking the beginning course in electrical engineering. At the

present time the work covered is so sketchy that the poor fellows have only the vaguest idea of what is going on and about all they learn is that they have a thorough dislike for anything electrical engineering. What would be wrong with having the mechanicals, civils, and others at least taking the beginning course presented to electrical engineers? Certainly the mechanicals, and perhaps others, need just as thorough a grounding in electrical engineering fundamentals as do the electrical majors.

Out in this Western country it is probably a good idea to have all students, be they civil or otherwise, take a course in surveying. So why should not all students be subjected to the same beginning course?

All schools do not require a course in heating and ventilating for mechanicals but apparently all architectural engineers have to take that course and many institutions have an elective course in heating and ventilating for mechanicals even if it is not required of them. I would again suggest that all people taking the heating and ventilating course be subjected to exactly the same treatment.

At the University of Wyoming we have just finished setting up new curricula since we are changing from the quarter system to the semester system of operation. While I had hoped that many more changes in the departmental curricula could be made, what changes have been made have been brought about in the direction of a unified curriculum.

The students have always taken the same mathematics, physics, chemistry, mechanics, fluid mechanics, and some others and now we have all the students taking the same thermodynamics and have all those requiring heating and ventilating taking exactly the same course. In other words we have done much to eliminate the so-called service course. The thermodynamics course has had a one-year trial and the heating and ventilating course has had a five-year trial. Both have been successful and the only trouble is that the civil engineers make better grades in thermodynamics than do the mechanicals and electricals. The heating and ventilating course taken by both the mechanical engineers and architectural engineers has not suffered materially in rigor over the course formerly given for mechanicals alone and in the combined course the architectural engineers do just as well as the mechanicals. We feel that we have made a right step in eliminating service courses. As I said at the outset we are supposed to give students something upon which they can build in the future and this cannot be done with much success with one of those bobtailed service courses with the theory all covered in the first 15 pages and the rest of the book devoted to thousands of words of description and hundreds of illustrations which are out of date before the ink is dry.

Too Much Material Covered in Textbooks

Another thing that I have been wondering about is why is there so much material covered in every textbook. No matter whether it is a book on power plants or internal combustion engineering or what, there is always a chapter on fuels and combustion. Why is this included here? Could this not be left out of all of them and given in a separate course in combustion? This would cut down the size of many textbooks and thus reduce their cost. I find also that several books have a chapter or two dealing with heat transfer. Most schools have a separate course in heat transfer so why should this material be included in several of the books secured by a student. In general, it is only covered once and that time in the heat transfer course for which a separate text is purchased.

These are only a few examples of stuffing texts and the first question that comes to my mind is whether or not a book has to be fat to be salable. Cannot

good things come in small packages? It has been my experience that all the material cannot be covered in every text anyway so why put so much into them. Every text should not be designed as a reference book or handbook.

I am also wondering if there could not be some realignment of existing courses. For instance, now that courses are given in steam turbines and gas turbines and in some cases hydraulic turbines, centrifugal pumps, fans, blowers, and so forth, the books I have scrutinized have considerable overlapping in the principles of operation of these devices. Perhaps some schools already do this but could not a course be given in rotating machinery which would apply to all these devices. Students have so much trouble carrying principles from one course to the next, perhaps if they could see how basic principles are tied together from one machine to the other, less confusion might result. I have only used one example here and that in mechanical engineering but I feel that other examples and in other departments could be brought to mind. For instance, all types of reciprocating machinery could be covered in a single course.

I believe that we try in all schools and in all departments to cover too much material. Generally speaking, it seems the students have been presented so many things and have such a vague knowledge of what they have learned that they are completely confused and have so very little confidence in what they are able to retain. I feel that many are in the same shape as a friend of mine who remarked on commencement day, "I know nothing and I've got that all mixed up." I think it is high time everyone took a good look at curricula and courses to decide what should be taken out rather than what should be put in. It certainly is true that if we expect to put in something we have to take out a like amount. I would like to see a group of top educators, preferably working through A.S.E.E., make a study and suggest what material and what courses should be deleted and what should be presented. If that were done and if laboratory equipment were prescribed or suggested it would be much easier to plan for an E.C.P.D. visitation and also so much easier to please the E.C.P.D. inspectors.

Before closing I should like to repeat that the material presented to students should be something upon which they can build in the future. While we in engineering should certainly look our courses over and decide what to throw out, I feel that the mathematics people miss the boat here as much or more than anyone else and they could so easily make a change. They try to give too much. The highest compliment I ever heard concerning a mathematics professor was paid to one on our campus when it was stated that this mathematics professor did not try to tell the students everything he knew. Incidentally, this mathematics professor is the most popular man in that department. I have often wondered why mathematics people put in so many extras which appear in the back of the book at the expense of teaching a few things well which appear in the front part of the book. If the procedure were reversed, the students would have a sturdy foundation upon which they could build by either course or individual study.

I dare say that there are students who come into their junior year who have never had pointed out to them which parts of the calculus book they will be needing during the next two years. They never seem to recognize nor are they able to handle the simple basic equations required in the junior and senior years but I think I know the answer why. They have been too busy sitting around watching a mathematics instructor spend hours and hours integrating and differentiating extremely lengthy and complex equations for which they will certainly have no immediate use and which perhaps have very little practical application.

I dare say that engineering sophomores are required to operate with equations which could not be set up by a single living soul in the states of Utah, Wyoming, or Colorado, except by a man who enjoys mathematical gymnastics. I feel that too many teachers, be they mathematics teachers or engineering teachers, are much more interested in teaching their courses than they are in teaching students.

In thinking of the reasons why so few people want to go into engineering teaching, I wonder if it is because we, as their teachers, have done such a rotten job that they do not want to be like us. Perhaps we have given them too much of the wrong thing. Perhaps our courses contain too many uninteresting and unimportant things or perhaps we have given them too much and merely caused them confusion.

I feel that it is high time we do everything we can to place greater emphasis upon basic ideas upon which our students can build in the future.

The Teaching and Learning of Engineering

By ERICH A. FARBER

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Whenever the question of what to teach the students of engineering in their college courses arises, little disagreement is found among educators and professional engineers. Everyone agrees to the magic words "The Fundamentals." When, however, it comes to defining these fundamentals, differences of opinion appear, and it is possible to get answers like "chassis design," "jet propulsion," and other fields of individual interest.

The student, on the other hand, often remarks "Why don't we learn something practical, rather than all this theory?," when his opinion is sought. However, when asked to define what he means by "Something Practical," he becomes confused and contradictory in his own statements.

Without reaching agreement on a definition of the fundamentals, the discussion usually leads to the question of how best to teach the students, inspire them, and prepare them for their future assignments.

It is important to keep the overall picture of what is to be accomplished in mind in any long range project such as the preparation for an engineering career, and to show the students how their immediate efforts lead to their ultimate goal.

This paper proposes a workable definition of the fundamentals, a method of showing the student the path leading to his ultimate goal, the importance of research, how to give students contact with practice, and the final product which can be obtained.

The Fundamentals

"The Fundamentals" shall be the laws of nature which govern the universe and are, for engineering purposes, often expressed in the form of mathematical equations or laws. It should be realized at this point that our understanding of the fundamentals is based upon our ability to recognize facts correctly and that they have to be revised from time to time as our understanding of these facts becomes more complete. They are not laws in the true sense of the word but rather a formulation of facts as best we see them. When, for convenience, the actual facts are expressed approximately by rather simple expressions, the limitations and restrictions should clearly be stated.

The Path Leading to the Ultimate Goal

Everything worthwhile which has been achieved by an individual, a group, or humanity as a whole was done by striving toward a definite, clearly defined—although sometimes unattainable—goal. All the efforts were directed and coordinated in this one direction and, if persistent, crowned with unbelievable success.

When applying this to the engineering field it is necessary for the teacher to point out to the student the desired goal and every time the student wanders off his course to remind him of the goal and bring him back to the path leading there. This will show the student why his efforts are necessary and the objective to which they lead.

The student has to be made to realize first that he needs the fundamentals. Actually, he gets them in his physics and chemistry courses. The writer himself realized this, not when taking physics, not even after graduation, but when, in his first teaching assignment, he was called upon to teach engineering physics. This

study opened his eyes, and he has since spent much time to help his students understand this.

Then, to be able to work with the fundamentals properly, certain tools are needed which are normally classified under the heading of "Mathematics."

The realization of the above will then show the student what his instructors are trying to do, and he will see how most of his courses during his first two years fit into this pattern.

Since knowledge is of little use to the person who has attained it if he cannot tell others about it, a certain amount of training in composition as well as in speech is desirable if not essential.

While the student is laboring with new concepts and definitions without apparent use for them, he has to be reminded that most of his time during the second half of his college career will be spent in learning the many things he can do with these fundamentals, and how the different fields are controlled by them. Here the range of application of each fundamental concept should be pointed out, giving each course a definite place in the total picture, rather than having a number of disjointed and disconnected courses. The similarity of courses with respect to their fundamental concepts is far greater than most students and many teachers realize. This similarity should be pointed out at every opportunity. For example, the student should be made to realize that he uses the same law of conservation of energy whether they call it Bernoulli's equation in hydraulics, the general energy equation in thermodynamics, or the energy method in dynamics. The same differential equation will solve problems in vibration, electrical circuits and heat transfer. As much as engineering students work with air as a medium, most of them are afraid to tackle mixtures of gases, combustion products, and saturated gases. It usually makes them feel much better when reminded that they have worked with air, and actual gas mixture, without undue difficulty for some time. Similarities of this kind within a course and between courses should always be pointed out.

Through further contact with research, as well as practice, the student's understanding and appreciation of these fundamentals will constantly grow, and his fields of application widen.

The Importance of Research

Up to the last year of the student's career, he has been guided by his teachers in and out of the class room and has been shown many things he can do with the fundamentals he learned earlier. His curiosity has probably given him some cause to wonder what and how much he could do on his own or with a minimum of guidance. Formal course work can never answer these questions, and, unless the student is given the opportunity to prove to himself that he can do things on his own, he will most likely take his first job not knowing his capabilities and afraid to try himself for fear of losing his job. He then leads a not-too-happy existence doing what he is told with little chance for further development.

Therefore in one informal course (and it is called "course" only for want of a better word) a certain project should be chosen by the student and the teacher, and then the student should be allowed to explore and develop it with only a minimum of guidance. The project should be defined in general terms only, so that he then can display his own ingenuity and approach, using the fundamentals which he has learned and has been shown how to use. This special project also demonstrates to the student the difficulty of obtaining accurate measurements; for instance, the temperature of a surface, a quantity which he may use many times in his course work. The student also gets the opportunity to apply accepted methods to his particular problem, and he will learn to appreciate difficulties actually encountered in the engineering field.

Many students have told the writer that they have learned more from one of

these projects than in many courses combined. For the first time they had to draw on all their background instead of on one chapter of a specific book as they did in working the problems at the end of it.

The teacher who engages in research will also be able to give the students something above and beyond the printed page in the book. He can explain and actually show the students difficulties encountered in particular problems and can give them information not yet available in published form.

The Contact with Practice

In many cases due to lack of understanding between the teachers of engineering and the professional engineers, theory is arbitrarily set aside from practice. This is indeed unfortunate, since practice would be lost without theory, and theory would have nothing to stand on without verification through practice.

If the engineering teacher is unable to leave teaching for any extended period to enter industry, he still has ample time and opportunity during the summer and especially through consulting to combine theory with practice. Whenever students come to him for something practical to learn, he can ask them questions which actually came up in his consulting work, and which they can answer with the theory learned thus far. After such examples, the question of theory versus practice does not come up again.

It is very helpful to give letters which are received from industry to the student, asking him to answer them before the instructor answers them himself. On numerous occasions, when agreeable with the companies, students can be taken on consulting trips and while in the background, can see how the theory which they learned in school can be and is applied in actual practice.

The Final Product

Thus, again summarizing the procedures recommended here, it seems of utmost importance to let the student of engineering know what the college has planned for him and why. The teacher has to point out to the student that first he learns the fundamentals and the tools to manipulate them. He is also being trained better to convey his knowledge to others. Then he is shown what he can do with these fundamentals in different fields of engineering, (always stressing the similarity rather than the differences).

Then, before graduating, during his last year he should be urged to apply his ingenuity and resourcefulness to a project of his own with only a minimum of guidance. To complete his training he should be asked to answer actual questions which came up in engineering practice, and, if possible, he should have the opportunity to see how practical problems are handled on the consulting basis.

On the day of graduation the student will know what his college tried to do for him, how well it succeeded, what his personal limitations are, and what is expected of him in the future as a professional engineer.

Polytechnical Instruction in Soviet Secondary Schools of General Education

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Concurrently with their drive for an ever increasing number of graduates from science and engineering colleges, Soviet planners recently turned their attention to secondary and elementary schools. *Polytechnical Instruction* is the term used to describe the new approach to education at all levels. It involves the introduction of some sort of practical technical training at all the stages of education, from grade school up to college. Like everything else in Soviet Russia, this move has a motivation both in Marxist philosophy and in the practical plans for the industrialization of the country.

From Lenin to the Nineteenth Party Congress

The principles of polytechnical instruction which "does not require teaching everything, but requires teaching the elements of modern industry in general" were first formulated by Lenin in 1920. He recommended the introduction of some limited form of polytechnical instruction even at that early stage of the development of the society which he considered not yet sufficiently mature for a full scale educational reform.

The aims and means of polytechnical instruction were further outlined in the directive of the Central Committee of the All-Union Communist Party dated September 5, 1931, which described it as the education "of universally developed builders of socialism, able to combine theory with practice and to master technology." This was to be achieved through general rather than specialized technical instruction, supplementing rather than replacing existing secondary school curricula. The directive further states that: "Any attempt to separate the polytechnization of schools from the systematic and solid acquisition of learning—physics, chemistry and mathematics in particular—the teaching of which must be based on rigorous and detailed programs, plans, and conducted according to the strictest schedules, represents a gross distortion of the idea of a polytechnic school."

Since 1931 articles of polytechnical instruction appeared from time to time in professional journals, but the idea was not introduced in practice. In October 1952, however, the Nineteenth Party Congress issued a directive for the "immediate application of elements of polytechnical instruction with only slight changes in the program, the textbooks, and the method of presentation" in all the secondary schools in the country. This measure was to coincide with the gradual transition to universal education on the secondary (high school) level first in large towns and industrial centers (1951–1955), and then in the rest of the Soviet Union (1956–1960).

* The following paper is a condensed version of a study prepared for the Center for International Studies at the Massachusetts Institute of Technology when the author was a Research Associate there in the summer of 1954. Facts and opinions expressed in the article are the individual responsibility of the author.

The directive of the Nineteenth Party Congress was first implemented during the academic year 1953/54, after a propaganda campaign using press and broadcasting media to popularize the principles of the reform. These may be summarized as follows:

a) Publishing of special textbooks with a "polytechnical approach";
b) Design and construction of special equipment for schoolrooms (*kabiniety*) and laboratories;
c) Production of numerous training films of polytechnical nature;
d) Publication of articles on the method of teaching industrial processes to the students;
e) Establishment of special training programs to prepare teachers for polytechnical training.

The Actual Meaning of Polytechnical Instruction

Let us now consider the meaning of polytechnical instruction and its effect on normal functioning of the Soviet schools.

Perhaps the best summary of rather lengthy descriptions of the reform appearing in the Party directives and publications of the Soviet Academy of Pedagogical Sciences is provided by a secondary school periodical "Mathematics in Schools," where polytechnical instruction is defined in the following manner: "Education familiarizing (the students) in theory and in practice with all the main branches of productive activities (*proizvodstva*)." Its main purpose is to "give an industrial worker education enabling him to understand the over-all picture of the branch of industry he is working in, and to give him enough general culture (*kultura*) to be sufficiently versatile for a rapid transfer to a different branch."

Polytechnical instruction in its elementary form is to begin as early as possible, suggest Soviet planners. Production of basic commodities of life, principles of farming, application of machinery, and the principles of communication can be outlined in simple stories adjusted to the intelligence levels of small children attending lower grades of elementary schools. This information should be supplemented with practical knowledge acquired through excursions into the neighboring plants, mills, and agricultural establishments.

As the children grow and mature towards the end of their secondary school studies, the load of polytechnical instruction increases, in particular with the introduction of more advanced sciences: biology, physics, and chemistry, and algebra and trigonometry in mathematics, in which the new kind of knowledge is to be constantly applied. A threefold objective is to be attained by the Soviet secondary schools in connection with the implementation of the program:

a) The level of basic theoretical knowledge is to be maintained and even raised;
b) The new kind of knowledge (*znaniye*) of the basic principles of industrial and agricultural production is to be acquired through the extended "polytechnical" curriculum;
c) New abilities (*umieniya*) and skills (*navyki*) are to be developed by the pupils.

According to the Academy of Pedagogical Sciences, the following elements of polytechnical instruction are to be incorporated in the courses of physics, mathematics, and chemistry in the senior grades of secondary schools:

Physics

Knowledge of important applications of physics in technology; principles of mechanical processes (machining) applied to metals; simple machines; basic principles of construction and operation of sources of mechanical energy; scientific principles of the electrification of the country; principles of "automation" and radio communication; transportation technique (principles of construction of

a steam locomotive, electric locomotive, motor car, tractor, steamship, airplane).

Abilities and Skills. Mastering measurement techniques: determination of weight, specific gravity, pressure, velocity, mechanical efficiency, temperature, quantity of heat, voltage and current intensity, brightness and illumination, etc.; mastering some manual skills; mechanical assembly work, electricity and radio modelling.

Mathematics

Knowledge of more important regions of application of mathematics in technology and production; coordinates; elementary functions; parallel projections as a basis for technical drawings; metrical relationships in elementary geometrical figures; derivative as rate of change of a process.

Abilities and Skills. Skillful mental and written computations; ability to approximate figures and to predict approximate results of operations; ability to use tables and references, abacus, logarithmic slide rule; ability to read a formula and to understand the way the magnitude it expresses varies when the components vary in a predetermined manner; ability to translate rapidly points into co-ordinates and vice versa; ability to use square-ruled paper; ability to make use of measuring instruments: the ruler, the tape, the measuring chain, the compass, the calipers, the set-squares, etc.; ability to take measurements in the terrain and to perform required computations, to calculate areas and volumes, to determine real sizes of plots from a plan of a given scale, to break up a plot into required fractions; ability to execute leveling, to draw diagrams; skills in analysis and synthesis of solid bodies; ability to set up and solve equations appropriate to technical and economic problems; ability to balance the credit-debit record sheet, to make an estimate, to keep financial records, books, etc.

Chemistry

Knowledge of the essentials and basic principles of production and application of substances in chemical industry; knowledge of more important branches of chemical industry; the types of raw materials, fuels, chemical fertilizers; typical facilities and supplies of a chemical enterprize.

Abilities and Skills. Handling vessels, instruments, reactors, electric appliances; recognizing substances important in practice and determining their composition; separation and purification of substances; selection of reagents in order to obtain a required substance; preparation of solutions and determination of their concentration; realizing chemical reactions in laboratory conditions.

The Magnitude of the Reform

The magnitude of the task seems to be well understood by the Soviet planners. The program is not to be introduced instantly in its full extent. A limited number of schools is to be affected by it during the current Five-Year Plan (1951–1955), and the remainder is to follow by 1960. In the meantime pressure is put on all concerned, teachers in particular, in order that the "norm" be "fulfilled," or better still, "overfulfilled." True, the teachers get considerable help of both quantitative and qualitative nature from the authorities. The directive of the Nineteenth Party Congress provides for an increase in the number of acceptances into Pedagogical Institutes (Russian Teachers' Colleges) of 45 per cent during the period 1951–55 over that of 1946–50, and considerable help is given to the teachers available at present in the form of the very detailed instructions, directives and recommendations from the authorities, as well as in the form of instructive articles appearing frequently in the specialized school periodicals which in the Soviet Union are of ex-

cellent quality and have a very large circulation.

Yet a teacher's lot is not an enviable one. Many teachers are considerably overworked—working two or even three shifts a day on a permanent basis; many of them are insufficiently qualified for the jobs to which they are assigned (elementary school teachers lecturing in secondary schools, etc.), in which case they are compelled to complete their formal education through evening or correspondence courses. Now a new burden is added: they have to acquire new skills necessary to teach polytechnical subjects, and supervise additional school activities of polytechnical nature, such as students' work in technical and scientific societies, excursions to industrial enterprizes, etc. Here are some guiding principles which, according to the directives of the Academy of Pedagogical Sciences, must be understood and complied with by all the teachers in connection with the reform:

1) The necessity of understanding the regular program in conjunction with polytechnical material; polytechnical material *must not* obscure basic knowledge;

2) Understanding the ideological value of polytechnical material added to the curriculum;

3) The use of polytechnical material so as to clarify material of general courses;

4) The necessity of using local facilities;

5) The necessity of using only that material which can be understood by the students.

There exists at the present moment a very considerable shortage of school buildings and supplies in the Soviet Union, and the additional requirements of the polytechnical program make that shortage even more acute. The directive of the Nineteenth Party Congress stipulates an increase in the construction rate of school buildings of 70 per cent in 1951–55 with respect to the preceding period, and there are vast plans for providing adequate school supplies. In the mean time, however, teachers are expected to show initiative in improvising as much as possible in the way of obtaining equipment from the local sources and furnishing the school workrooms.

There is an interesting institution in the Soviet Union, peculiar to their system, known under the name of "patronage" (*shefstvo*). Almost every organizational unit has its "patron" institution whose purpose is to provide some kind of overseeing of the activities of the "ward" unit, ranging from political control to providing material help. In the case of schools, local industrial enterprises are nominated to be their "patron" organizations, and in many instances they seem to be the only sources supplying the equipment required for polytechnization.

It is interesting to note that the improvization goes often as far as expecting students to provide their own equipment for the laboratory experiments or furnishing the workrooms. No mention is made, however, of the sources from which the equipment is to come in such cases.

Some help is provided by Polytechnical Museums, or Polytechnical Sections in museums of general nature, very numerous in the Soviet Union. It is difficult to see, however, how they can help much since their equipment is usually in short supply also.

As with everything else in the Land of the Soviets, this educational reform must follow the line of Marxist philosophy by being revolutionary in its nature. Its constructive part is to be inseparable from or even preceded by the "liquidation" of an old and alien ideology, represented in this case by "formalism," meaning any abstract ideas in teaching.

A permanent vigil in the fight against "formalism" is being constantly advocated, which in practice amounts to re-

moving from the programs and from the text-books all the problems that have no direct and obvious connection with the requirements of economy or technology. Every theoretical part of the course is to be immediately illustrated with real, practical examples, always stressing requirements of Soviet industry and agriculture and the part played in that particular field by the native (Russian) scientists and inventors.

The Difficulties and the Possibilities

Such are the official policy and the objectives; such is the wishful thinking of the planners. The effects, assuming that the program is eventually fully carried out, may reach a scale unprecedented in the history of education. Is it possible to realize it? Is it not too big and too difficult for the limited capabilities of human nature which can withstand the stress and the strain only up to a certain limit of endurance? These are the questions which we shall now attempt to answer.

There are many and serious difficulties, no doubt. Shortage of teachers; their insufficient qualifications, made more serious by the requirements of the new program; additional effort required of them for numerous extracurricular and out-of-school activities; more factual material required of the students to memorize; lack of additional equipment and accommodation for its use.

At first glance the difficulties appear unsurmountable, and one is tempted to conclude that the program is bound to be a complete or at least a partial failure. One is certainly tempted to draw this conclusion on the basis of observing an educational system appropriate to a Western community. When, however, one considers Soviet schools, their conditions of work and other characteristic features peculiar to their environment, the conclusion becomes less obvious and one hesitates to pronounce the final judgment. There exist several reasons for which we think the reform is more likely to succeed in a totalitarian state than in a Western democracy.

1) We believe that there is high pressure put on both teachers and pupils in connection with the reform: successful ones are rewarded, and the failures castigated in the familiar fashion. There are many ways in which this can be done in a totalitarian state.

2) Both teachers and pupils are accustomed to hard work through long hours, and they know that it is normal for their output to be expected to increase permanently.

3) There is a considerable attractiveness in the program, especially to the young people growing in the atmosphere of hero-worship surrounding an industrial worker, an engineer, and now a scientist. All papers, periodicals, and radio are full of it, and it is no wonder that youngsters believe that inventing new methods of high speed metal cutting or of more efficient excavating are deeds of the highest moral and spiritual value.

In addition to this it appears that Soviet planners are more reasonable in carrying out the reform than they were, for example, in the case of collectivization of farms, which produced such catastrophic results. The educational reform is to be implemented gradually and over a considerable period of time, thus reducing the possibility of its being a failure, especially since no violence will be necessary in this case.

We conclude, therefore, that in spite of all the difficulties, we are inclined to believe that the Soviet Union is on the path of achieving a complete politechnization of secondary schools. It will make very slow progress since the difficulties are many and the obstacles hard to overcome, but if the policy remains unchanged for some time to come, and if the objective is pursued with the same vigor and enterprise with which it was

begun, the polytechnization of secondary schools will prove to be the most revolutionary and by far the most successful contribution in converting the Soviet Union into the leading industrial state, and the final goal set up by its leaders "to overtake and to pass" (*dognat' i pieriegnat'*) the West apparently will have been achieved.

Final Implications and Conclusions

And now the question arises as to whether this reform is the right path for the development of any modern society, and is it to be followed by all those who do not want to be left behind?

Three distinct aspects can be discerned in the complexity of the picture: first, a short range objective of building a highly industrialized society and state; second, an attempt to create a universally developed man, combining theoretical knowledge with practical skills; and third, achieving this through a perfect balance between theory and practice in the field of education, expressed so eloquently in the exposition of "formalism" and in the necessity to fight against it.

There seems to be no doubt that to the first objective, a rapid industrialization of the country, polytechnical instruction is a positive contribution. The fact is being recognized outside of the U.S.S.R., and when one studies directives and recommendations of various Boards of Education in the United States, one finds references to "elements of polytechnization" often outdoing those appearing in the Soviet literature. Polytechnization is, at least for the time being, of a greater urgency in Russia, since it is one of the very helpful factors in filling the still existing gap between the laborer and the engineer which, in most Western countries with an older industrial tradition, has never existed.

The second objective inherent in the idea of polytechnization is the creation of a man of "universal culture" necessary, according to the prophets of Marxism and Leninism, for the development of a truly communist society. We would be inclined to agree, perhaps, that a nation composed of Leonardo da Vincis is an advantage with respect to the one composed of average men. The question arises, however, whether it is possible even to approach such an ideal, and whether it would suit the majority of the persons concerned?

There is a school of thought according to which maximum output is obtained from any undertaking if the objective of it is set at an unattainable level. From this point of view asking too much of an average Soviet citizen does make sense. If he is compelled to strive to become a manifold genius, he may eventually attain a higher level of professional development than he would have done without this special inducement, thus becoming a more valuable asset to the state. On the other hand a vast majority of people have no such far-reaching ambitions, and it is doubtful whether they would display too much enthusiasm in collaborating with the idea. Furthermore, at the present stage of development of industry and argiculture and the associated division of labor, there are still many jobs requiring people with limited ambitions and capabilities. Here Leonardo da Vincis would be out of place and would become an additional problem. Of course, with further progress in different fields the situation will change, but until this happens the aims of polytechnical instruction with regard to creating universally developed members of society may be considered premature.

Third and last: the basis of polytechnical instruction is to be a perfect balance, a perfect harmony between theory and practice. No theory detached from practical application is to be entertained, no abstract, "formalistic" ideas are to be tolerated.

At first glance this seems to be a very reasonable scheme, especially in Russia and for the Russians who were famous in the pre-Leninist era for their out-of-this-world ideas. These are now to make room for practical plans leading towards real and definite objectives.

When it comes to expanding highway or canal systems, designing new types of computing machines, or even developing multi-dimensional geometries for specific purposes, the scheme will work beautifully and efficiently. But for how long will it last? How long will it be before the existing patterns of scientific thinking are exhausted and the progress is slowed down or stopped? Is it possible to kill "formalism"—the abstract, the detached thinking—without killing progress itself so often emanating from this kind of thought?

It is our contention that in the long run the abstract is just as necessary as the immediate reality. And not only for its own sake, but for the sake of that very reality of which it appears to be a most striking contradiction. After all, where would the electrical or aeronautical engineering sciences be today if Cauchy had been forbidden to develop his functions of complex variable, based on the concept of imaginary numbers, the very name of which implies things alien to practicability? Where would modern technology be today without inventions of Faraday, "as useless as a newborn baby," or theorems of Taylor unrecognized even by his fellow-mathematicians for a long time? And where would we be without "formalism" of Euler or Lobachevsky, who is now treated as if he were a "Hero of the Soviet Union"—a century after his death—in spite of his most abstract ideas, certainly deviating from the straight and narrow path of Marxist realism?

So it appears to us that a free enquiry of inquisitive minds, unrestrained and unrestricted, can never be replaced by any planned development no matter how perfect. Let us not be ashamed to look for answers to any question, no matter how useless or absurd it may seem. With this we may reasonably hope to remain in the future, just as we have been in the past, ahead of the others, without fear of being permanently passed or overtaken.

On Teaching Creative Engineering*

By C. D. FULTON M.E. Professor Duke

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"The only proper study of mankind is man"
—Pope

It is highly anomalous that American engineering educators have done so much to discourage ingenuity in young men striving to be Ingenious Ones. We have tried to make machines of our students and to convince them that thinking is not good engineering. We have taught them to seek every answer in books and rules, to distrust their own minds for any purpose except mechanical sorting, and to be ashamed of an idea that they could not document. Fortunately, we have not succeeded; our graduates have adapted themselves to the very different real world of practice and have put their imaginations to work as their Creator intended.

How did we fall into this dismal error? Some say that out of sheer laziness we took the easy and secure way to teach, but they overlook the fact that sincere and ambitious teachers were equally dedicated to that way. No, we believed in it. Perhaps we inherited it from the old grammarians who thought to make poets through spelling and punctuation. Perhaps we caught it from the scientists. We may have invented it ourselves. In the final analysis, however, we believed in it because we came to worship sacred-cow science. Our dream of perfect engineering was a digital computer, a shipload of punched tapes, and no human beings to spoil the results.

The physicists had the same trouble. In the twenties, they began to believe that the universe could be reduced to protons and electrons hooked up by Einstein's equations. The answer to anything was supposed to be in the formulas if one took long enough to grind it out according to the rules. But today, a chastened physics profession is valiantly trying to recapture the many strange creatures that have flown out of its Pandora's box, and they suspect that even if they manage to clamp the lid shut, it will pop open on another day.

The sacred cow is dead and its reeking carcass should be hauled out of the engineering classroom.

Progress in Engineering Education

We are in the midst of genuine forward steps in engineering education. Perhaps they began with the Wickenden report with its call for a cessation of divisions of curricula and its insistence upon lifelong education. Next came the strengthening of the humanities in the curriculum and then World War II with its countless stimuli. Today there are more signs of progress: the rise of engineering research; new evaluation studies by this Society, with their call for emphasis on the engineering sciences; new studies and the beginnings of instruction and writings on the art of en-

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gineering teaching; and now the return of creativity from exile.

The engineering sciences which we are now called upon to emphasize must not be like the old scared-cow sciences. They must be dynamic. We must teach them as flexible tools which an engineer can employ when they are useful, not as millstones about his neck. The engineer must be educated for change not impressed from without but springing from within himself.

Creative engineering is being rescued from the pedagogical dungeon by pressures from all sides even including engineering sales. The degree to which this emancipation has already progressed is indicated by the reversal in our attitude toward Edison who, twenty years ago, was generally regarded with a mixture of envy and suspicion but today is being recognized as one of the greatest of our profession. But creative engineering is still going to have a difficult time making its way into our classrooms because we are so steeped in our set-rule methods that we shall not only be reluctant to give up their comfortable ways but find it hard to develop new ones for lack of knowledge. There is virtually no documentation on creative engineering and it is enmeshed in psychology. As a result we shall find ourselves trying to catch a ball in the sun with a glove that we don't know how to use. It may well take us a generation to learn how to teach creative engineering.

In spite of these difficulties, if we will maintain the progressive pace now evident in engineering education, we may yet reach the point where we can begin to lead the profession instead of following two decades behind it. Perhaps we shall also learn how to teach engineering with an efficiency of 15 per cent instead of 10 per cent.

Convention and Creativity

A study could be made of the operations of engineering—such acts as setting up an equation, fitting parts together in a sketch, predicting whether a quantity increases or decreases, or deducing the mechanism of a process. While there are surely many possible ways of categorizing the operations, it will be sufficient for present purposes to recognize only two categories, the conventional and the creative. In another age these terms might not make sense.

Conventional engineering, which we have been teaching, is a network of formulas, data, rules, and static science bound into a firm discipline. It demands rationality, order, repetition, patience, caution, thoroughness, and scholarship. The more one adheres to a predetermined step-by-step process, the better conventional engineering does he do and the more inevitable is the result. This kind of engineering is a machine-like process and machines are beginning to be employed to do some of it. It is indeed a considerable part of engineering and we have done a good job of teaching it.

Creative engineering, on the other hand, operates on emotion, imagination, chance, boldness, rebellion, abandon, flight of fancy, and every other quality which distinguishes the live human being from the inanimate machine. What we mean by creative engineering is suggested by naming a few of its great practitioners: Watt, Faraday, Kelvin, Otto, Diesel, Edison, the Wright Brothers, Marconi, Ford, de Forest, Whittle, and Shockley.

The creative act is one of the least understood of human adventures. For that reason we look with awe upon it; we feel an elation; it seems that a divine spark strikes within us and for a moment we transcend ordinary existence. Even if we had to proceed with no more knowledge of the creative act than we have now, however, we could do a far better job of teaching creative engineering than we have done.

But it would be the ultimate pessimism to believe that creative thinking must be forever unknowable, for history abounds

with examples of how light has been cast on mysterious phenomena when they have been studied conscientiously. If we will devote ourselves to the task, we shall surely be able to strip away some of the mystery of the creative process and thereby increase our power over it. It is certainly not the mere play of chance; it must be the end result of a series of experiences, stimuli, and mental processes which can be identified and analyzed, and then effectively cultivated. In this research we shall have to depend heavily upon the psychologists. Let no one fear that the dignity of the human spirit will be diminished: as we learn more about the human being, our awe increases with our power.

Enlightenment of this kind will give us tools for teaching creative engineering in a straightforward manner. Instead of providing suitable soil and simply hoping that plants will spring up in it, we shall be able to sow the seed and cultivate the plants. Inasmuch as we needed this information yesterday, we had better get started.

The Hats

If creative thinking were for the few, this discussion might end here. It is true that some engineers are born with more creative ability than others and that some engineering operations require more creativity than others, but the plain fact is that every engineer—researcher, designer, tester, manager, salesman, and all—faces situations demanding creative thought in every move he makes. He must conceive a series of little inventions of scope, interpretation, assumption, emphasis, choice, procedure, and evaluation. The warp of these inventions combined with the woof of conventional knowledge makes the cloth of engineering.

Or we might draw another analogy. Conventional engineering is a thin network of roads across the world of engineering. The roads are sometimes very good like Newton's laws, and sometimes they are merely trails like convective heat transfer. As long as one stays on the roads, he only goes where someone else has gone although he may improve the roads. To go anywhere else he must hike off into the wilderness without signs or comforts. Sometimes great discoveries lie a short distance from the roads; sometimes an exhausting exploration produces nothing.

Engineering is a succession of conventional and creative operations and the engineer must be able to change back and forth from the conventional to the creative hats as he moves through the various stages of a problem. The degree to which one of the hats sticks on his head when it should come off is a pretty good measure of what mistakes in judgment he will make, while the rapidity with which he can change hats is a fair measure of his speed and versatility. There are men who cannot take their own analytical results and apply them sensibly to the physical situation at hand. The conventional hat is stuck on their heads. There are also men who, while excellent experimentalists, cannot integrate their work into the stream of knowledge. The creative hat is stuck on their heads.

I experienced a costly example of the stuck conventional hat when working on a refrigerator for ultra low temperatures in 1949. By making calculations based on extrapolated data, I proved that a certain part should be $\frac{1}{8}$ inch in diameter. A year and many exhausting experiments later, that part was still conducting 500 times too much heat and I ended the project discouraged, having tried one scheme after another to cure the trouble. Still another year later, I was mulling over the mystery for the nth time when it dawned on me that if the part was conducting 500 times too much heat, what I ought to have done was forget calculations, theory, and all and make it 500 times smaller. Sure enough, a few months later came new measure-

ments from England showing that the heat conductivity of solid helium at ½ degree Kelvin is 500 times greater than had been supposed in 1949. How easy it would have been to save my project and beat the Englishmen to the draw if I had only taken off the conventional hat and put on the creative one at the right time!

If all this is so, we ought to teach it systematically in the classroom. We ought not to pretend that the conventional hat is the respectable one and that the creative hat shows up a fellow as a scientific tramp. Nor should we pretend that we are wearing the conventional hat all the time when we are actually switching hats. Fortunately, students tend to do as we do more than as we say do, but if we will both do and say the same thing, will it not produce better results?

Another weakness of our old methods is that most of our classroom problems are artificially contrived with half the creative thinking already done. How poorly our students do when confronted with an entire machine interacting with its environment and asked to find the problem, identify the important parameters, reduce the situation to its essentials, and get a theory! How poorly they integrate the pills of knowledge that we call courses!

We should not only teach them how to change hats but also give them material calling for plenty of practice in that art.

History, the Untapped Resource

By largely ignoring its history, the engineering profession has passed up a rich source of inspiration and wisdom. All that most of us know is a few names and dates and a handful of anecdotes. We must learn our history. Then we must teach it.

But lifeless history would be useless. To catalog inventions is an abominable way to teach history but it has been tried on occasion. To list scientific discoveries and principles is abominable but that has been tried also. History can be magnificent if taught in terms of the flesh and blood human beings who made it—in terms of their hopes, fears, struggles, mistakes, and triumphs. We should teach it as an integral part of every course.

To expound the First Law of Thermodynamics without telling about the Caloric Theory is a crime. To say that Diesel developed the most efficient of engines without telling how it would not even propel itself for three years is a crime. To discover the Wright Brothers at Kitty Hawk just when their contraption is ready to fly without telling how they had come to that great moment is a crime. To say that Midgley discovered tetraethyl lead to be a knock inhibitor without mentioning that he had first tried 600 other substances is a crime. Our whole scheme of presenting a finished idea to our students as if it had sprung full blown from the head of Zeus is incredibly bad.

We ought to teach a natural law or engineering development as a prize of war captured by the human race in a struggle in which Newton or Ericsson or whoever it was was the victorious general. We should tell about the losing side—who they were, what they advocated, and why they lost. By teaching how we came to be where we are, we will teach how to extrapolate into the future. Such teaching will be a powerful way to build creative engineering.

History will bring other advantages beyond the scope of this paper but I cannot refrain from mentioning two of them. The first is that the historical method is by far the best way of teaching a difficult concept, like entropy for example. Since nobody ever taught me how Clausius actually invented entropy, I am using a little fable temporarily. I have no doubt that the actual story will be better than my fable, which begins, "Clausius was strolling down Unter den Linden one Sunday afternoon in 1847

when he said to himself, 'Mein Gott, it giffs isotermal und isopiestic und isovolumetric prozesses, but vot in Himmel iss konstant in ein reversible und adiabatische expansion?' "

The second advantage is the enormous cultural benefit of integrating engineering history into the minds of the engineering profession. It is partly because of our ignorance of history that we appear unlettered and unpolished to many people. It is there that we could find some of the continuity, cohesion, poise, judgment, and insight that we sorely lack.

Unfortunately, this reform cannot be carried out in the near future because of the appalling vacuum in adequate historical works on engineering. Most of the existing ones are written by laymen or for laymen and fail to convey the inside story of the scientific and intellectual experiences of the protagonists. Nor is there enough engineering history in the textbooks to fill a thimble. Source material is hard to find and we have let many of our historical streams dry up. There is therefore the tremendous preliminary job of getting this material into useful form and disseminating it. This will require years of work by literate engineers well attuned to human passions and willing to do a lot of hard digging. Here is another piece of research that we needed yesterday.

Creativity in Textbooks

The general deficiencies now discernible in our textbooks cannot be laid to the authors. Textbooks are an organ which cannot progress faster than the educational animal; indeed, they lag behind because they must be built on pedagogical certainties. Publishers are conservative. So, unfortunately, are professors when they choose books for the next term.

Whatever has been wrong with engineering teaching has therefore been even more wrong with the textbooks. Most of them have been written entirely in the conventional engineering mode and have catered to sacred-cow science. They have developed the student's power of digestion, not his power of finding food. Principles have been laid down with Olympian assurance in defiance of experience which guarantees that within the lifetime of the student those principles will be greatly changed. There has been virtually no history: everything has sprung out of thin air. Creativity has starved to death.

There are, however, some additional problems particularly relevant to textbooks. One of the reasons that many of them have been little more than catalogs is the well known pressure to include every development in the technological field being written on. The result is that the author who has tried to include even a representative sample has been painfully squeezed. He has become frantic to meet the requirement of coverage and has had no room left for such luxuries as history, exploratory discussion, philosophy, or self-discovery —in short, for creativity. Today, the luxuries begin to look more and more like essentials, and coverage more and more like a luxury. The textbook of the future will use applications only as means of teaching basic science and not as ends in themselves. In this way the pressure to include this or that development will disappear; the real pressure will be to include the science and to present it in a creative manner.

A more subtle problem is that most textbooks have been tacit combinations of educational and reference works and have consequently failed to be either. The requirements of the two are incompatible. Is the student who is trying to grasp the First Law of Thermodynamics enlightened by an array of assumptions, special cases, and equations? No, but the engineer who is trying to find out how to write the centrifugal work term in the First Law for gas flowing through a helicopter blade is not helped by a dis-

cussion of Joule's experiments. The time is ripe to design educational works solely for educational purposes. This too will make room for creativity. Fortunately, our technology is becoming big enough to support two systems of books.

Creativity also suffers from an uninspired style of writing and from dullness of composition and arrangement. Literary artistry is just as much needed in an engineering textbook as it is in a novel.

Enlightened authors are already putting some of these reforms into practice. Too much cannot be expected too soon, for the way to write the textbook of the future is certainly not yet known. Experiments will be necessary and some failures are bound to occur. The rate of progress will depend to a very great extent on how much support the teaching profession gives improved textbooks as they appear. Let it never be said by a publisher that he offered us the kind of textbook that we say we need and we would not use it.

The Next Frontier

In instituting all these improvements, we shall have our hands full for a long time. But what will be the next frontier? Shall we wait until we are again behind the times to begin the reforms that will be due a generation hence? No, let us move into a continuous research program that will keep us ahead of the profession as we ought to be.

If we call the next unknown quantity X, perhaps we can derive it by extrapolating the change now in progress in engineering education—the change from applications to sciences or from convention to creativity. Then we would write

$$\text{Applications}:\ \text{Sciences} = \text{Sciences}:\ X$$

or

$$\text{Convention}:\ \text{Creativity} = \text{Creativity}:\ X$$

We are ascending the scale from the specific to the general or from the effect to the cause. Then X, the next frontier, must be a deeper understanding of the principles underlying all science and creativity.

What will be the nature of this understanding? Let us suppose for the sake of discussion that the rise of science during the past three centuries was caused by the advent of three new ideas which were added to the ancient idea of inductive reasoning. The first new idea was the overthrow of the hyper-Aristotelian doctrine that reasoning is more to be trusted than experiment, in favor of the counter-doctrine that experiment is indispensable. This meant that you ought to do a lot of tinkering and that if you saw a light stone and a heavy stone fall at the same rate you ought to leave off believing that they fall at different rates.

The second idea was that you ought to measure everything and express it in numbers. This also meant that you ought to develop instruments.

The third idea was the new mathematics crowned by the calculus.

Assuming all this, we have a sort of recipe that says to put these four ingredients into the human being and you will get the kind of science we have had. It is time to probe beneath this empiricism. We know very little about the psychological reactions in the mixing bowl. We do not know how to vary the recipe to get other and perhaps better combinations.

Or perhaps the next frontier will lie in a slightly different direction suggested by Percy Bridgman's observations on the Paper and Pencil Operation.* He points out that in solving a certain type of problem we go through four steps in which we first explore and define the problem, then write down the laws that we need to solve it, then go into an opium fog where we turn the mathematical crank according to established rules (the Paper and Pencil Operation,

* P. W. Bridgman, *The Nature of Thermodynamics*, Harvard University Press, 1941.

divorced from physical reality), and finally emerge with an answer which must be interpreted back into the physical world. Bridgman has thus done an operations research into a small part of science. Perhaps studies of this kind are what we shall need.

The problem may be hazy but we must not be so shortsighted as to discount it. If the blacksmith of 1820 had said that there was no need to know more about the heat treating and alloying of steel, he would have been short-sighted. And if we artisans of engineering today say that the science of engineering thought and creation need not be explored, then we are short-sighted and we shall be left standing on the platform when the train pulls out.

We shall have to pay more attention to the psychologists. Our present coolness toward them is attributable not so much to their difficulties, as we claim, as to our incomprehension of a field foreign to our way of thinking but increasingly impingent upon our needs.

Whatever answer lies ahead, it will improve our teaching. Then we shall not have to teach nine, or fifteen, or thirty basic engineering sciences as separate disciplines, but we shall be able to teach a single discipline of which these sciences are applications! Then the efficiency of engineering education may rise from 15 per cent to 20 per cent. The solution to the increasing complexity of the age will be, as always, to consolidate on new and broader philosophical levels.

Teachers Above All

Methodology and reform are useful but the indispensable ingredient of education will always be the teacher, upon whose genius and devotion everything depends. Of all the qualities spoiled by a dull teacher, creativity is hardest hit. We need better men in engineering education; we need the very best that the profession can muster.

It is one of the scandals of engineering education that most engineering teachers are thrown into teaching without any formal preparation for it. Only because we have much company in other college professors do we get by with this laxity. The American Society for Engineering Education has made a good start toward attacking this problem; let us help it redouble its efforts. Let us write books on engineering teaching and offer a course on it in every engineering graduate school.

If we will develop our teachers as we should, we can win the reputation of being one of the most enlightened groups in college education.

Conclusions

1. If engineering education will continue to reform, it can eventually begin to lead the engineering profession.

2. Creativity, long neglected and discouraged in engineering education, is beginning to receive attention. Educators should uproot sacred-cow methods and develop methods for teaching creative engineering. This will be difficult and will take time. Research on the creative process should be pressed.

3. All engineering is a series of creative and conventional operations and engineers should be able to change rapidly back and forth from the creative to the conventional hats. This procedure should be taught rationally. Creative thinking should not be distilled out of classroom problems.

4. Engineering history should be dug out by researchers and put into usable form. It should be taught as an integral part of every course, not as a course by itself. It should not be a dead chronology, but an intimate account of the experiences of real men with their difficulties, mistakes, and triumphs. Concepts and principles should be introduced by the historical method.

5. Textbooks should be redesigned to inculcate creativity. They should teach engineering sciences using applications

as means and not ends. Coverage of developments should be sacrificed in favor of history, philosophy, self-discovery, style, and composition. Educational textbooks should be distinct from reference books, research papers, or other forms of writing.

6. Research should be done in the science of engineering thought and discovery. This research should utilize psychology to the fullest extent. The results will permit further improvements in engineering education.

7. Engineering teachers should be the best men that the profession can muster. Their training should be earnestly developed through every available means including courses and books.

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The Engineering School of Tomorrow

By MILTON O. SCHMIDT

Professor of Civil Engineering, University of Illinois

The engineering school of tomorrow will be the hallmark of those professional attitudes, ethical principles, and intellectual attainments which are seriously needed today by America's engineers as they seek unity among themselves and a better measure of recognition from their fellow citizens. The engineering school of tomorrow mindful of the great charge entrusted to it—to educate rather than to train—will break sharply from the mold in which engineering institutions have been cast in this country for the past 100 years. It will set itself resolutely to the task of securing dignified respect for engineering as it educates young men to fulfill the highest concepts of ethical conduct, technological achievement, and social understanding.

The forerunners of the engineering school of tomorrow may be the five-year curricula institutions who are offering a broader educational base for professional practice. A lesson could be taken from the programs of the dental and medical schools who have insisted upon pre-professional training for several decades. May it not be refreshing that engineering students be introduced to the disciplines and values of letters and arts. May it not be wise that they demonstrate higher proficiencies in oral and written expression before they enter a school designed for young men who have the mental and moral fiber needed to lend strength to a profession which is old in years but may not yet have come of age.

The emergence of the engineering school of tomorrow from the school of today will not be rapid or assured. Its metamorphosis will depend largely upon the quality of its staff, the careful choice of students, and upon the organization and administration of curricula. The task of redefining the structure of American engineering education will demand the best efforts of bold and imaginative administration with principles such as the following forming a guiding framework:

1. Professional rank and title will be guarded more zealously. Academic title will not be prostituted by the inadequacy of budget. Mediocre staff will not be recruited with the allurement of title when funds are insufficient to employ competent personnel. It will not be assumed that a good engineer is also a good teacher. Hence, the situation of a former downtown engineering assistant suddenly finding himself invested with the title of professor will not be permitted.

2. Schools will be on guard to prevent the appointment of too many of their own graduates unless they have been elsewhere since graduation and have been leavened by contact with the practice of engineering and by teaching experience at other schools. To neglect these precautions will be to invite not merely academic inbreeding but intellectual incest.

3. Increasing emphasis will be given to the appointment of professors of wide general intellectual interests as opposed to the engineering recluse who ordinarily lacks the perspective or the desire for effective exploration of new educational channels or may be incapable of generating a desire for learning.

The better professor will aid his students to appraise things at their true values, to seek out the truth on all issues

and to act as valiantly for the unpopular beliefs as those which are more palatable but no more sound. He will urge them to view objectively the special interest groups, the trade unionists no less than the P. E.'s, and to beware of the false prophets.

4. The teaching loads will give opportunity for continued individual study, reflection, and self-improvement, for the true engineering professor must embody the principle of continuing adult education he seeks to preach in his classes. For him there can be no release from the constant demand to know more about men and machines. This insatiable curiosity to learn all interrelations is a true index of the learned one—the professor. Woe to the school that casts the magic mantle of tenure over the soft shoulders of those who delight in the academic life because of the opportunity it affords to spend the generous hours away from the classroom in the prosaic pursuits of domesticity, in hobbying, following the telecasts, and other intellectual-numbing activities.

5. The tendency of the young instructor to engage in outside work will be viewed with concern if such experience is routine and of a production nature, and the teacher uses the advantages of a salaried position to compete with other engineers. Good teaching is considered a full-time enterprise which can be best strengthened and steeped in engineering practice by gaining creditable experience during leaves of absence with reputable engineering organizations.

6. The attainment of intellectual capacity and the development of an ethical sense will gain ascendancy over the importance of engineering procedures and practices since the engineering school of tomorrow will consider itself the standard bearer of the engineering profession and the co-guardian with the technical societies of its integrity.

Students

The engineering school of tomorrow will give vastly more consideration to the selection of its students. It will realize that their quality is much more important than their numbers. It will effect liason with the technical institutes so that capable technicians can be trained from among those not capable of surviving the rigors of the professional engineering school.

It will launch extensive programs of aptitude testing to determine the capabilities of each applicant for admission. In its study of candidates the school will spare no efforts to portray the nature and extent of engineering employment—its shortcomings and its triumphs—for more than anything else must there exist in the make-up of the prospective student a great desire to become an engineer.

Administration

The engineering school of tomorrow will break boldly with tradition on matters of organization and administration of its curricula. It will recognize the essentially fluid character of academic programs of study and acknowledge they are constantly in transition.

Its administration will be quick to detect sycophancy in its staff. It will be able to distinguish between ordinary authorship that may break into print and quality scholarship; between the scurry and disorder of undistinguished committee work and the high quality of unrecognized student counselling; between departmental clerking and virile instruction. It will not be intimidated by cries of academic imperialism and taunted into submission or retreat when the issues of the day and the responsibilities of administration call for prompt and decisive exercise of authority to accomplish action. It will recognize it is better to deliver on time while occasionally making mistakes than to breed the air of uncertainty and indecision which is engendered by endless delays and habitual vacillation in executing policy.

Finally, the distinguishing feature of a university education should be a widening and deepening of intellectual capacity and

power. The engineering school of the future, usually attached to a university, will not tolerate mediocrity in any area. It will strive to give its graduates a sound understanding of fundamentals and enrich and strengthen their intellectual resources. By accomplishing this it will serve notice to the world that engineering and engineers have finally come of age. Not until such time as the engineering school of today becomes the engineering school of tomorrow will the engineering profession be able to dissolve the miasma of uncertainty, ordinary stature, and lack of professional recognition that envelop engineers today.

The Integration of Humanities into an Engineering Program

By J. STUART JOHNSON

Head, School of Electrical Engineering, Purdue University, Lafayette, Indiana

A great deal has been said, and printed, on the subject of the need for liberalizing an engineering education. Surveys have been made by engineers and liberal arts people alike, in an effort to determine the desirability of inclusion of material in the social-humanistic areas in an engineering curriculum, and to determine the amount and type and degree of coverage of such material.

I would like to submit that any number of credit hours will not accomplish the desired purpose unless the necessary stimulation is provided. I would like to submit further that a long sequence of courses in any one small area of the entire field will not necessarily provide that stimulation.

A few years past, a magic number of 20% was proposed as the minimum amount of nontechnical material which should be included in an engineering undergraduate curriculum. Many schools attempted to adjust curricula to fit this magic number. A few took the term "minimum" in its literal sense, and held strictly to this amount. Others went far beyond it. Still others, however, argued that the amount of time available for engineering work was not sufficient, and did not reach the 20% figure.

I believe that it has been recognized by all concerned, recently, that the specification was not based on firm foundation. It is not argued that engineering graduates should not be acquainted with philosophy, psychology, history, and the various subjects generally considered in the arts and sciences area. Nor, I believe, is it a matter of disagreement that persons trained in the fields of history and sociology should present this material to the engineering student. My thesis concerns merely the manner in which this material is presented, together with the intensity of presentation in any one area.

Three Stages

I would contend that there are three stages through which the liberalizing processes go. Briefly, these would be the introduction to the subject by the specialist, the continued application of the material as a part of a technical course, and third, the self-development of the student after graduation. I would contend that an engineering program which, exclusive of English composition, grammar, and speech, includes one course per semester in each of several areas of the social studies and humanities, would serve as the training field corresponding to the first stage. I would not propose, however, that a course in history in the junior year be taught as what might be termed an introductory course in history, or a more detailed course in history covering a specific period of time, such as might be taught to an arts and sciences student, who conceivably would take more courses in the field. I would suggest that the single course be taught with a view to identifying the impact of history and historical events on the student's own profession. Similarly, I would feel that a course in government, rather than representing a detailed study of governmental

structure, be slanted toward impressing the student with the effect of matters pertaining to governmental organization and action on the engineering profession.

In other words, a fundamental course in each of several areas in which the subject is closely identified to the student's own profession, in such a way as to show him his professional relationship with these various areas, would, I believe, serve as a strong stimulus.

The second stage of the student's training in the so-called social-humanistic stem would be obtained in the actual professional courses themselves. There is no reason why the engineering instructor cannot, and should not, continue to identify the professional field in its relation to history, government, economics, and similar areas considered as nontechnical. This, of course, would require an appreciation on the part of engineering faculty members of the importance of these areas as well as an ability to link the two things together.

If the student had passed through these two stages in the proper manner, I feel reasonably confident that he would have been imbued with the belief that his profession is not isolated, but is an important part of a much larger field. Having gained the stimulation through these two stages, he should not only be capable of, but desirous of, continuing to establish the further relationship after graduation.

It is believed that the above procedure would result in a broader coverage of nontechnical topics in a relatively conservative amount of time, insofar as the percentage of time devoted from the engineering program is concerned. It is also believed that the approach designed to relate the nontechnical areas to the student's professional activity would provide a stimulation for further study in the area. It is still further believed that the engineering program itself might take on more value as a result of the relationship which would be established between the two areas.

Candid Comments

By H. A. MARCOUX

Professor of Mechanical Engineering, University of Arizona

In the college of engineering our freshman students are confronted with a problem which must be common to every university student. Sooner or later they realize that since their classroom work will become increasingly technical and demanding, the burden of obtaining a broader and more rounded education must, of necessity, be carried by the individual. There is a definite advantage in having this situation become clear-cut and obvious early in one's university career. Basically, it confronts every student whose pattern of interests and habits is in the formative stage—and some who have begun to question the established routine of their college life.

The well educated man is not merely technically proficient in his chosen field, but, above all, possesses intellectual and social maturity. This distant goal cannot be attained automatically by passive attendance, however frequent, at the many and varied activities which university life encompasses. Exposure to the fields of literature, art, music, history, philosophy, and science is, of course, a prerequisite to an intelligent and respectful appreciation of the facets which comprise the background of a well-rounded education. But education is an active process. An individual must experience actual reactions to these outside stimuli. If the reaction is one of satisfaction, of deepening interest and awareness, a process of intellectual growth is set up. This can only be accomplished by a deliberate effort on the part of the student to develop within himself a state of readiness and receptivity which will transcend that required for classroom routine.

The degree of accomplishment in any particular field is selective—and, compared to a specialist, very limited. However, there are rich rewards for the smallest efforts toward broadening one's horizons. One can find a greater sense of personal fulfillment, a truer concept of one's effectiveness and status in our society, and a broader understanding of human relations. If his development is genuine and complete, a habit pattern will be set up which will enable him to continue throughout his life to grow and develop—to choose the more stimulating book, appreciate the finer music, and be more tolerant toward his fellow men.

Industry Views the Engineering Graduate and His Curriculum

By WILLIAM K. LEBOLD

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Purpose

When the national committee on the "Evaluation of Engineering Education" was organized by the American Society for Engineering Education, each engineering school was asked to form a study committee to consider the overall phases of engineering education. At Purdue University a Curriculum Study Committee was appointed to consider the general problem of determining the educational requirements of graduate engineers "competent to serve the needs of the engineering profession over the next quarter century." Purdue's committee was aware of the close relationship existing between the faculty and those leaders in industry responsible for the selection, placement, and development of engineers. In view of this relationship, the committee requested industry's leaders to provide information concerning the present supply and future demand for engineers trained to various educational levels, and in addition, to give their opinions regarding the content and duration of engineering curricula.

Procedure

A questionnaire was prepared to meet a twofold purpose:

1) To determine the distribution of engineers among the various job categories in which engineers are generally employed and to determine what difference, if any, the level of degree makes, and
2) To determine the attitudes of industrial leaders in regard to engineering curricula.

The selection of companies and the individual within each company was important. The following criteria was used:

1) From a list of 800–1000 companies who send representatives to interview potential engineering graduates, typical companies were selected.
2) From the companies chosen, a further selection was made of those individuals in industry which committee members felt were in a position to supply reliable answers.

One of the assumptions underlying the questionnaire is that engineers can be classed into one of three categories defined as follows:

A. "Those who deal primarily with new technical ideas or products. This would include research, development, design, etc.," hereafter in this report referred to as *New Developments.*

B. "Those whose primary function is the operation of existing facilities or the execution of existing plans or designs. This would include production, construction, operation, service, etc.," hereafter referred to as *Operations.*

C. "Those who deal principally with the human element in technology. This would include production, supervision, sales, personnel work, etc.," hereafter referred to as *Human Relations.*

About 170 companies that employ engineering degree personnel were sent questionnaires together with an explanatory letter. In general, the questionnaire was addressed to the person in charge of engineering college recruitment. Usable ques-

tionnaires were received from 85 companies or approximately 50% of the total. The questionnaire was for the most part filled out by the addressed person, although he occasionally referred it to one or more persons in his respective organization.

The companies responding included those in the aircraft, chemical, food, electrical, heavy machinery, and metal trade industries as well as railroads, utilities, and a world-wide construction firm.

Results

The questions submitted to industry's leaders are given in Appendix A together with summary tables. The results have been grouped into two major divisions:

1) A classification of employees with engineering degrees—Questions No. 1 to 6.
2) Engineering curricula opinions of industrial leaders—Questions No. 7 to 12.

Engineering Degrees and Job Categories:

The first question in the questionnaire asked for the number of engineering degree employees in each of the participating companies. Question No. 1 reads as follows:

Approximately how many persons with engineering degrees does your firm now employ?

The questionnaire came from companies employing anywhere from 13,375 to 3 engineering degree persons. The median number of engineering degree persons employed was 277 among the 85 responding companies. (See No. 1, Appendix A for a Frequency Distribution.)

In view of the job categories previously defined, *New Developments, Operations,* and *Human Relations,* the questionnaire asked:

"2 *How many of your employees having engineering degrees can be classified in each of the categories?*"

The complete results are tabulated in No. 2, Appendix A. A breakdown of 1953 engineering degree employees is as follows:

Those having Bachelor's degrees accounted for:

83.8% of those in New Developments
95.9% of those in Operations
93.3% of those in Human Relations
or 90.1% of those in all three categories.

Those having Master's degrees accounted for:

13.0% of those in New Developments
3.9% of those in Operations
6.4% of those in Human Relations
or 8.4% of those in all three categories.

Those having Doctor's degrees accounted for:

3.2% of those in New Developments
.2% of those in Operations
.3% of those in Human Relations
or 1.5% of those in all three categories.

The overall breakdown indicates that at the time of the survey the responding companies had engineering degree employees classified as follows:

41.9% were active in New Developments
30.4% were active in Operations
and 27.7% were active in Human Relations.

The responding companies employed a total of 75,565 engineers, a fairly large sample of the national engineering degree population (estimated to be about 400,000).

To determine what type of demand could be expected for engineering graduates the questionnaire asked: "*How many engineering graduates would you*

like to hire during 1953?" The total figures indicated a demand for 10,439 engineering graduates or 13.8% of those employed at the time of the survey (early 1953). (See No. 3, Appendix A.)

To determine the job categories in which 1953 graduates might eventually be employed, Question No. 4 asked: *"Of the engineering graduates you would like to hire in 1953, how many would you expect to be employed in each of the categories after five years of service?"* (See No. 4, Appendix A.) Those having Bachelor's degrees would account for:

82% of those in New Developments
94% of those in Operations
93% of those in Human Relations
and 88% of those in all three categories, after five years of employment.

Those having Master's degrees would account for:

13% in New Developments
5% in Operations
6% in Human Relations
and 9.5% in all three categories.

Those having Doctor's degrees would account for:

4.6% of those in New Developments
.6% of those in Operations
1.2% of those in Human Relations
and 2.8% of those in all three categories.

Industry estimated that those they would liked to have hired in 1953 would after five years service be distributed as follows:

53% in New Developments
28% in Operations
and 20% in Human Relations.

The discrepancy between the totals in Question No. 3 (10,439) and Question No. 4 (9,703) is due to the fact that some respondents did not answer Question No. 4.

To determine future demands the questionnaire addressed itself to the same general problem 10 years hence (1963). Question No. 5 asked: *"How many engineering graduates would you like to hire during 1963?"* All respondents did not answer this question; nevertheless the projected total was 10,314 or 15% of those (early 1953) employed in the companies answering this question.

Question No. 6 again asked for a classification of 1963 graduates according to the type of degree: *"Of the engineering graduates you would like to hire in 1963, how many would you expect to be employed in each of the categories after five years of service?"* (See No. 6, Appendix A.) Those having Bachelor's degrees after five years service would account for:

74% of those in New Developments
92.8% of those in Operations
89.8% of those in Human Relations
and 83.7% of those in all three categories.

Master's degrees based on these estimates after five years service (1968) would account for:

18.1% of those in New Developments
6.4% of those in Operations
7.6% of those in Human Relations
and 12.0% of those in all three categories.

Doctor's degrees would account for after five years service:

7.6% of those in New Developments
.7% of those in Operations
2.5% of those in Human Relations
and 4.3% of those in all three categories.

Again the totals in No. 5 and No. 6 do not agree, since not every respondent answered No. 6.

Engineering Curricula

The curriculum question was first mentioned in No. 7 which asked: *"Do you believe that the undergraduate college training should be different for the different categories listed after Question No. 1?"* (New Developments, Operations, and Human Relations). Of the 85 questionnaires received, 40 (47%) answered in the affirmative, 41 (48%) in the negative and 4 (5%) either did not respond or qualified their answer.

Those favoring different training for the different categories were then asked about subject matter as follows: *"If your answer to No. 7 is yes, what subjects should be emphasized to a greater extent for each category? (check one or more).* (See No. 7, Appendix A.) Those subjects checked 50% or more were:

In New Developments:

Advanced Science	65%
Engineering	50%
English—Speech	84%

In Operations:

Engineering	55%
English—Speech	73%
Economics—Psychology—Government	67%

In Human Relations:

English—Speech	97%
Economics—Psychology—Government	92%
Humanities	76%

It is important to note that *only* those who answered "yes" to Question No. 7, namely those in favor of different undergraduate training for engineers in New Developments, Operations, and Human Relations, answered this question.

The four-year vs. the five-year program was faced in Question No. 9 which asked: *"Do you favor a four year or a five year curriculum for the Bachelor's degrees in engineering?"* Opinion was again about equally divided, 43 (51%) favoring the four-year curriculum and 42 (49%) favoring the five-year program.

Those favoring the five-year program were then asked: *"If you favor the five-year curriculum, what subjects would you like to see emphasized to a greater extent?"* (See No. 10, Appendix A.) Those subjects checked more than 50% of the time were:

In New Developments:

English—Speech	90%

In Operations:

English—Speech	90%
Economics—Psychology—Government	74%
Humanities	51%

In Human Relations:

English—Speech	94%
Economics—Psychology—Government	81%
Humanities	75%

Only those favoring the five-year program answered this question.

The integrated program was considered in Question No. 11 which asked: *"Do you think there is need for an undergraduate curriculum offering an integrated, across the board type of program with emphasis on the subject matter and methods common to the major fields of engineering?"* There were 50 (59%) "yes's," 21 (25%) "no's," and 14 (16%) did not respond to this question. Those answering "yes" favored such a program for 42.2% of the undergraduates. (See Appendix A, Question No. 11.)

The relation of the technical institute program to engineering was approached in Question No. 12 which asked: *"If graduates of technical institutes (2 year training) were available in sufficient number, what percentage of the engineers you are now hiring would you be willing to replace by those with technical institute train-*

ing?" Some did not respond to this question and others commented that they would hire more technical institute graduate but not to replace engineers. The respondents' answers resulted in a 9.8% mean, more than one-half indicating that they would not hire any technical institute graduates in *place* of engineers.

Summary

As is often the case in designing a questionnaire, certain modifications seem desirable after the results are in. The results should be thought of as more or less qualitative in nature, since they lack the quantitative precision that engineers are accustomed to in physical measurements. The classification of employed engineers into the categories is based upon thousands of engineers, Questions No. 1–6. On the other hand the questions concerning the curriculum are based on the individual opinions of the 85 industry representatives who answered the questionnaire, Questions No. 7–12.

1. Industry indicates that about 4 out of 10 engineers are engaged in New Developments (research-design), 3 out of 10 in Operations (production-construction), and about 3 out of 10 in Human Relations (sales-supervision). About 9 out of 10 have Bachelor's degrees, about 1 out of 10 have Master's degrees and about 1 out of 100 have Doctor's degrees (varying from 4 out of 100 in New Developments to 2 in 1000 in Operations).

2. Based on the estimates for 1953 and 1963, industry would like to hire about 1 engineer for every 10 currently employed.

3. Industry indicated that during the next ten years a greater percentage of those with Master's and Doctor's degrees will be desired, but Bachelor's degrees will continue to constitute better than 80% of demand.

4. Those in charge of industry's college recruiting programs were about equally divided on specific training of undergraduates for particular job categories, as contrasted with training in a common program for all job categories. Those favoring more specific programs prefer more advanced science and engineering for those in research and design, more social sciences for those in production and construction, and more social sciences and humanities for those in sales and supervision. Additional English and speech training seemed to be highly desirable for all job categories.

5. The replies indicated that industry was about equally divided between the four-year and the five-year programs. Those favoring the five-year program generally favored more humanities and social sciences for construction and production personnel and more social sciences and humanities for sales and supervision personnel. Again there was general unanimity on English and speech, over 90% of the respondents checking these subjects.

6. Fifty-nine per cent of the respondents thought there was a need for an integrated undergraduate program which would emphasize subject matter common to the major fields of engineering. Twenty-five per cent did not think there was a need for such a program and the remaining 16% did not respond to this question. Those who thought there was a need for an integrated program thought that about half of the students should take such a program.

7. It seems unlikely from the responses received that technical institute graduates will be hired instead of engineering graduates.

In closing it seems advisable to point out that these results in general represent the opinions of a limited number of key industry men who represent a small but important segment of industrial managements' opinions.

Acknowledgments

The important contributions of the industries cooperating in this survey are gratefully acknowledged. Without their help the survey would not have been possible.

The "Questionnaire on Evaluation of

(the) Engineering Curriculum" was prepared by a Curriculum Study Committee at Purdue consisting of:

H. T. Amrine	W. E. Howland
C. L. Brown	T. J. Hughel
F. L. Cason	H. F. S. Jonah
P. F. Chenea	Hsu Lo
G. R. Cooper	G. E. Spencer
B. L. Dodds	H. L. Solberg, *Chairman*
J. O. Hancock	

The original study committee deserves special credit for its foresight and insight in conceiving and designing the survey.

This report was prepared with the guidance of Purdue's Engineering Education Committee.

The Engineering Education Committee includes:

Paul Alexander	G. E. Spencer
C. O. Bennett	K. B. Woods
J. B. Jones	J. L. Waling
Hsu Lo	L. E. Beck, *Chairman*
W. J. Luzadder	

The suggestions of this committee are gratefully acknowledged.

APPENDIX A

Summary Tables of the Questionnaire on Evaluation of the Engineering Curriculum

1. Approximately how many persons with engineering degrees does your firm now employ?

Range: (3–13,375)
Median: 277
Frequency Distribution:

Number of Engineers	Number of Companies
7000–up	1
6000–6999	2
5000–5999	1
4000–4999	0
3000–3999	2
2000–2999	3
1000–1999	8
500– 999	17
300– 499	6
200– 299	11
100– 199	14
50– 99	11
0– 49	9
Total	85

2. How many of your employees having engineering degrees can be classified in each of the categories?

Degrees	Job Categories			Total Degrees
	A. New Developments	B. Operations	C. Human Relations	
	Number %	Number %	Number %	Number %
Bachelor's Degree	26,541 83.8%	22,056 95.9%	19.489 93.3%	68,086 90.1%
Master's Degree	4,119 13.0%	895 3.9%	1,346 6.4%	6,360 8.4%
Doctor's Degree	1,016 3.2%	42 .2%	61 .29%	1,119 1.5%
Total No. Degrees %	31,696 41.9%	22,993 30.4%	20,896 27.7%	75,565 Grand 100% Total

3. How many engineering graduates would you like to hire during 1953?

Numbers of Graduates	Per Cent of Grand Total—Question No. 2
10,439	13.8%

4. Of the engineering graduates you would like to hire in 1953, how many would you expect to be employed in each of the categories after five years of service?

Degrees	Job Categories			Total Degrees
	A. New Developments	B. Operations	C. Human Relations	
	Number %	Number %	Number %	Number %
Bachelor's Degree	4,200 82.2%	2,507 94.0%	1,797 93.1%	8,504 87.6%
Master's Degree	670 13.1%	145 5.4%	108 5.6%	923 9.5%
Doctor's Degree	237 4.6%	15 .6%	24 1.2%	276 2.8%
Total No. Degrees %	5,107 52.6%	2,667 27.5%	1.929 19.9%	9,703 Grand 100% Total

5. How many engineering graduates would you like to hire during 1963?

Number of Graduates	Per Cent of the Adjusted Grand Total
10,314	15.0%

6. Of the engineering graduates you would like to hire in 1963, how many would you expect to be employed in each of the categories after 5 years of service?

Degrees	Job Categories			Total Degrees
	A. New Developments	B. Operations	C. Human Relations	
	Number %	Number %	Number %	Number %
Bachelor's Degree	2,751 74.9%	2,275 92.8%	1,804 89.8%	6,830 83.7%
Master's Degree	663 18.1%	158 6.4%	153 7.6%	979 12.0%
Doctor's Degree	281 7.6%	18 .7%	51 2.5%	350 4.3%
Total No. Degrees %	3,700 45.3%	2,451 30.0%	2,008 24.6%	8,159 Grand 100% Total

7. Do you believe that the undergraduate college training should be different for the different categories listed after Question No. 1?

Response	Number of Responses	Per Cent of the Returned Questionnaires
Yes	40	47%
No	41	48%
No Response or Qualified	4	4.7%

8. If your answer to 7 is yes, what subjects should be emphasized to a greater extent for each category? (check one or more)

Subjects	Job Categories		
	A. New Developments	B. Operations	C. Human Relations
	Number of Checks	Number of Checks	Number of Checks
Basic Physics, Chem., Math.	15 48%	10 30%	8 22%
Advanced Physics, Chemistry, Math.	20 65%	2 6%	0 0%
Engineering Fundamentals (Mechanics, Thermo. Elec. & Magn.)	18 58%	18 55%	12 32%
Specialized Technology	15 48%	11 33%	3 8%
English—Speech	26 84%	24 73%	36 97%
Economics, Psych. Government	7 23%	22 67%	34 92%
Humanities (literature, philosophy, etc.)	5 16%	6 18%	28 76%
Total	31 100%	33 100%	37 100%

9. Do you favor a 4 year or a 5 year curriculum for the Bachelor's degree in engineering?

Response	Number of Responses	Per Cent of the Returned Questionnaires
4 year curriculum	43	50.6%
5 year curriculum	42	49.4%

10. If you favor the five year curriculum, what subjects would you like to see emphasized to a greater extent? (Check one or more)

Subjects	Job Categories		
	A. New Developments	B. Operations	C. Human Relations
	Number of Checks	Number of Checks	Number of Checks
Basic Physics, Chem., Math.	5 16%	4 13%	2 6%
Advanced Physics, Chemistry, Math.	11 36%	4 13%	2 6%
Engineering Fundamentals (Mechanics, Thermo. Elec. & Magn.)	15 48%	11 36%	7 22%
Specialized Technology	10 33%	8 26%	4 13%
English—Speech	28 90%	28 90%	29 94%
Economics, Psych. Government	15 48%	23 74%	25 81%
Humanities (literature, philosophy, etc.)	13 42%	17 51%	23 75%
Total	31 100%	31 100%	31 100%

11. Do you think there is need for an undergraduate curriculum offering an integrated, across-the-board type of program with emphasis on the subject matter and methods common to the major fields of engineering?

a)

Response	Number of Responses	Per Cent of the Returned Questionnaires
Yes	50	59%
No	21	25%
No Response	14	16%

b) If so, what percentage of students should take such a program? *Mean* 42.2%
Median 50.0%

12. If graduates of technical institutes (2 year training) were available in sufficient numbers, what percentage of the engineers you are now hiring would you be willing to replace by those with technical institute training?

Mean: Number of engineers 9.8%
Median: Number of engineers 0%

New Members

ALLEN, CAROL W., Instructor of Mechanical Engineering, Purdue University, Lafayette, Indiana. E. S. Ault, Allen S. Hall, Jr.

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MECHANICAL ENGINEER—SOMEONE to teach heat subjects and normal mechanical engineering laboratories. Should be active in technical and professional organizations. Salary and academic rank depending upon degree and experience. Position starts September, 1955. Location, Ohio.

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Section Meetings

Section	*Location of Meeting*	*Dates*	*Chairman of Section*
Allegheny	Bucknell University	April 29–30, 1955	W. D. Garman, Bucknell University
Illinois-Indiana	University of Notre Dame	May 21, 1955	G. E. Ellithorn, University of Notre Dame
Kansas-Nebraska	University of Nebraska	Oct. 22–23, 1955	G. W. Bradshaw, University of Kansas
Michigan	Michigan State College	May 7, 1955	C. C. Sigerfoos, Michigan State College
Middle Atlantic	Swarthmore College	May 7, 1955	H. N. Jenkins, Swarthmore College
Missouri-Arkansas	University of Missouri	March 26, 1955	M. M. Jones, University of Missouri
*National Capital Area			J. C. Michalowicz, Catholic University
*New England			E. R. McKee, University of Vermont
*North Midwest			C. J. Pratt, Michigan College of M. and T.
Ohio	University of Akron	May 7, 1955	K. F. Sibila, University of Akron
Pacific Northwest	University of Idaho	April 15–16, 1955	M. L. Jackson, University of Idaho
*Pacific Southwest			B. M. Green, Stanford University
Rocky Mountain	Colorado A. & M. College	April 16, 1955	D. F. Peterson, Colorado A. and M. College
Southeast	University of Tennessee	April 14–16, 1955	H. V. Flinsch, Mississippi State College
Southwest	University of Oklahoma	April 8–9, 1955	V. L. Doughtie, University of Texas
*Upper New York			B. H. Norem, Syracuse University

Members of the Society are welcome at all Section Meetings

* No date set.

A SUMMER COURSE IN

Plastic Design in Structural Steel

Presented by *Lehigh University* and *The American Institute of Steel Construction* in cooperation with *The American Society for Engineering Education* and *The Engineering Mechanics and Structural Divisions* of The American Society of Civil Engineers

The Fritz Engineering Laboratory

LEHIGH UNIVERSITY

Bethlehem, Pennsylvania

September 7–15, 1955

During the past quarter-century, both in this country and abroad, research on the ultimate strength of steel structures has suggested challenging possibilities for the use of maximum (plastic) strength as a basis for structural design.

Traditionally, the measure of steel's total strength for construction purposes has been the largest load under which it is guaranteed to behave in a truly elastic manner. Present day building codes, based upon the elastic concept, are logical and economical for individual beams and pin-connected frames.

When members are rigidly connected, however, the structure as a whole has long been known to possess a much greater load-carrying capacity than indicated by the elastic concept. These continuous (or "rigid") frames are able to carry increased loads above "first yield" because structural steel has the capacity to yield plastically with no loss of strength; indeed, with frequent increase in resistance. This behavior results when the rigidly connected, continuous structure draws upon the reserve strength of its less heavily stressed portions.

Sensing the values to our economy of a full exploitation of this more realistic measure of steel's strength, Lehigh University began in 1937 a series of research projects on rigid steel frames and their components which still continues. Since 1946 the studies have been under the sponsorship of the American Institute of Steel Construction, the American Iron and Steel Institute, the Welding Research Council, and the Navy Department. The latter includes The Office of Naval Research, The Bureau of Ships, and The Bureau of Yards and Docks.

By the summer of this year, sufficient data will have been compiled to document the new design concept—calling upon the "ultimate" strength of structural steel as revealed by analysis of its plastic rather than elastic behavior under load.

The resulting techniques, already successfully applied in England, promise to produce substantial savings in cost through the more economic use of steel and savings in the design office made possible by the more simple plastic methods. At the same time, building frames will be more logically designed for greater overall strength.

In order that educators in particular may have an opportunity to introduce these new concepts into their teaching at

the earliest possible date, a special "summer" session has been arranged just prior to the opening of the fall college term.

The course will review the behavior of steel structures loaded beyond the elastic limit and will present the fundamental concepts of plastic analysis. Specific plastic design techniques will be presented and examples worked out. The course will consist of a series of lectures and demonstrations, the latter including actual tests of structures to illustrate the principles. These tests, which will be carried through the elastic and plastic ranges, will include columns, continuous beams, and full-sized connections of the type found in industrial buildings. Also, a complete frame will be tested, illustrating the accuracy with which the true strength of a steel frame—its "ultimate" strength—may be predicted.

Each of the lectures in the Summer Course will be an hour long with a fifteen minute intermission between the two morning lectures. For those attending who are interested in the further discussion of particular points, informal discussion sessions will be arranged during the evenings at Fritz Laboratory.

All lectures will be given by members of the staff of the Fritz Engineering Laboratory who have participated extensively in this research investigation for the past several years.

Continued from page 821

CHRYSLER INSTITUTE OF ENGINEERING

again has openings on its full time teaching staff. They are:

1. Supervisor of engineering graduates working on individual automotive design projects as a part of their Graduate School course. Duties would also include supervision of graduate classwork.

   Desired qualifications: Age 25–40; B.S. degree or higher in engineering; at least 2 years of college teaching experience; some design experience, preferably automotive.

2. Teacher and supervisor of Graduate School classwork. Qualifications: Age 25–40; M.S. degree in engineering; experience in teaching mechanical engineering subjects.

Please write to—

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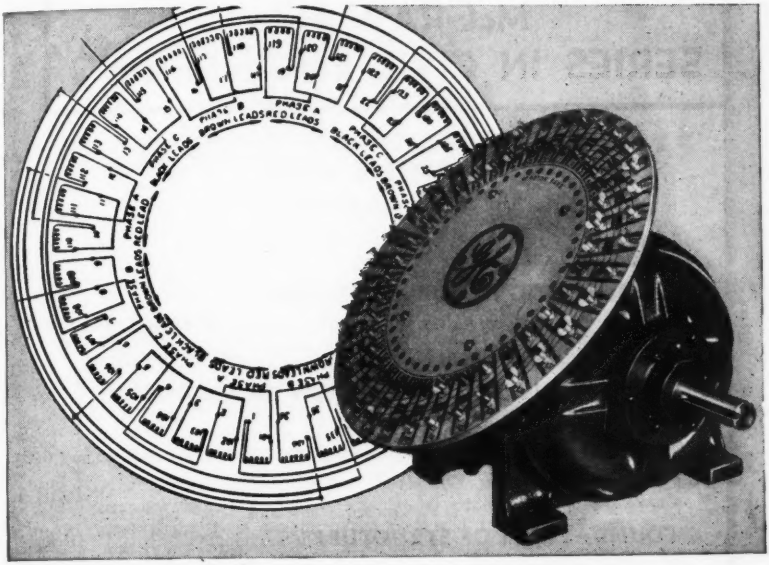

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